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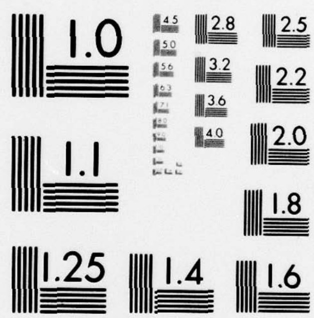

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CONTENTS

Telecommunications Technology in the 1980s*

Walter S. Baer

If technology is indeed a main engine of social change, we might be curious as to what lies ahead. This chapter describes some of the advances in telecommunications technology that can be anticipated during the 1980s. But what follows is intended neither as a technological forecast nor as an assessment of present and future technologies. In a field as rich and rapidly changing as telecommunications, any attempt to predict the technology of 1990 is doomed to failure. One need only look back an equivalent time span—from 1977 to 1964—to see the difficulties inherent in such forecasting.

In 1964, the technologies that seem most significant today were little more than laboratory developments or systems in their early experimental stages. Although communication by satellite had been successfully demonstrated with the Telstar, Relay, and Syncon projects, the first commercial satellite system was still a year away from launch. No one knew how well commercial communications satellites would perform, or for

*This paper was prepared for the Aspen Institute for Humanistic Studies, Program on Communications and Society, and appears as Chapter 2 of Communications for Tomorrow: Policy Perspectives for the 1980s, edited by Glen O. Robinson, New York, Praeger Publishers, 1978. It is reprinted by permission of the Aspen Institute for Humanistic Studies.

how long they would operate reliably in orbit. Computers were in the midst of a technological revolution from electron tubes to transistors, but computer users still brought stacks of punched cards to a machine room and waited for the results to be printed out on paper. Computer time-sharing was in its first stage of commercial introduction by General Electric and IBM. AT&T was looking ahead to its first installation in 1965 of a commercial computer-controlled, electronic switching system. Cable television had scarcely begun to attract notice as an industry with the potential for far more than retransmission of television broadcasts in areas that lacked adequate broadcast signals. And although the invention of the laser in 1960 had generated new interest in optical communications, practical applications seemed many years away.

This snapshot from 1964 suggests the pitfalls inherent in trying to track the precise path of technological evolution. Still, a look backward suggests some generalizations over the past 13 years that may extend into the future. First, new technological developments have primarily been applied to improve existing communications services rather than to create new ones. Television transmission by satellite across the oceans is one of the few examples of a new communications service introduced since 1964. Most technological advances have been used to reduce costs and improve the performance of services and products that were already offered—such as long-distance telephone calls, data transmission, and color television sets.

A second, related observation is that technological advance in telecommunications has been incremental and often invisible to those outside the field. Microwave and coaxial cable transmission of telephone traffic are two examples of technologies that have shown steady, incremental progress. Of course, over a period of a decade or more, gradual technical improvements can make large differences in the availability, performance, and cost of communications services. Thus, evolutionary changes can appear to outsiders as a communications "revolution." The Marxian view that quantitative changes cumulate to qualitative, revolutionary advances may have more technological than historical examples.

Third, even after new telecommunications technologies have proved economically advantageous, they take a long time to diffuse into widespread use. By 1964, electronic switching, satellite communications, and digital transmission lines were all reasonably well-developed technologically. Their introduction and commercial growth have been determined more by requirements for compatibility with the existing network, by the

availability of capital, by depreciation policies, and by regulatory constraints than by their technical "ripeness." A time scale of 20 years or more from commercial introduction to mature saturation seems typical for a system-oriented and highly regulated industry such as telecommunications. Technological advances have been introduced more rapidly in the less regulated industries, such as computing. Consequently, one can expect that the technological developments to be introduced into telecommunications in the 1980s are available in laboratories and experimental systems today. Most have already been widely discussed in the technical literature.

This chapter is based on the published literature, on my knowledge of developments under way in corporate and government laboratories, and on my discussions with many people personally involved in telecommunications technology. However, the conclusions basically reflect my own judgment about the pace and direction of technological developments in telecommunications. And, of course, history will undoubtably prove these conclusions wrong in many respects.

A few additional caveats are in order. The chapter describes technologies which are likely to find application in commercial systems in the 1980s, not those that seem more likely to remain in the laboratory or in the experimental stages. Consequently, the discussion reflects judgments about economic as well as technical feasibility (all costs are estimated in 1978 dollars). Despite their importance, this chapter does not consider regulatory and other policy issues in any detail. Many of these issues are treated in subsequent chapters of the book. Finally, the chapter does not systematically cover military developments or those primarily under way in other countries, except where those technologies seem likely to be applied commercially in the United States by 1990.

Computer and Component Technologies

The "microprocessor revolution," "intelligent terminals," and "teleprocessing networks" are by now familiar cliches. These terms reflect a convergence of communications and computing technologies that, of all technological changes, will have the most profound effects on telecommunications in the 1980s. This technical convergence—the combination of information-processing (computing) and communications functions in new hardware devices and systems—has already begun. Telecommunications systems are extending and integrating their use of computers for storage of information, conversion of electronic signals

from one form to another, switching, and network control. Computers increasingly interconnect through communications networks to provide their users with access to more computing power and sources of information.

The growing use of information processing in communications systems is due to the dramatic improvements in cost, performance, and the size of computer hardware. An information-processing system contains three basic units: the computing or processing unit, memory systems for storing information, and input/output units for maintaining external contacts. The costs of the information-processing and storage units have fallen by a factor of three every two years or so for the past 20 years—a total cost decrease of more than 10,000-fold. This means that a few hundred dollars in 1978 buys the equivalent computing power of several million dollars in the mid-1950s. The size of processing and storage units have also shrunk by a factor of about 10,000, while their speed (measured in the number of instructions or calculations processed per second) has increased approximately 50,000-fold. Manufacturers expect these trends to continue at least into the early 1980s.

The Computer on a Chip

Computer processors have gone through three major technological changes in components—from vacuum tubes to transistors, from transistors to integrated circuits, and from the early forms of integrated circuits to today's large-scale integrated (LSI) circuits. The LSI manufacturing process uses photolithographic and chemical techniques to build tiny regions with different electronic properties on a thin silicon "chip." These regions form the transistors, diodes, resistors, and connecting pathways that make up an LSI device. A computer processor built with LSI technology is called a microprocessor.

The advantages of LSI technology include the high density of components that can be packed on a single chip, greater reliability and less power consumption than individual components, and low incremental production costs. The first microprocessor chip, introduced in 1972, contained about 5,000 components. *(see Table 2-1)* With today's state-of-the-art, about 18,000 components can be placed on a chip that is roughly one-half a centimeter (0.2 inch) square. Such a microprocessor contains about four times as many components as a hand calculator and has more computing power than the largest computers assembled 25 years ago.

By the early 1980s, continuing improvements in LSI technology should yield commercial logic devices with roughly 60,000 components per chip.[2] These microprocessors will be able to execute four million instructions per second—roughly four times the speed of microprocessors today and 100 times faster than the small computers of the early 1960s. The cost of such devices depends critically on the number produced, but with volume production, they should cost less than $100 by 1980. Smaller capacity microprocessors that now cost $10 to $20, such as those used for programmable calculators and television games, should be available to manufacturers for between $1 and $5.

Today, engineers design new products with the assumption that computer-logic hardware is essentially free. The software is not free, however, and software costs increasingly dominate the expense of building sophisticated logic and controls into other devices. Microprocessors are now incorporated into scales, cash registers, machine tools, and most electronic instruments that cost $1,000 or more. Electronic calculators and home television games are the first consumer products to include microprocessors, but the technology is also being rapidly applied to automobiles and such other consumer items as ovens, washing machines, and dishwashers. And as described below, microprocessors are finding their way into communications equipment of all sorts, including point-of-sale registers, private switching facilities (PABXs), typewriters, data terminals, and even the telephone itself. The microprocessor signifies the demise of the centralized computer controlling the equipment connected to it. In its place, "intelligent" terminals and devices distribute logic throughout a communications network and perform complex tasks under the control of their own, built-in microprocessors.

Memory Devices

Computer processors are useless without information-storage devices, or *memory systems.*[3] Memory systems are of two basic types: primary memory units, which store the processor's instructions and the basic data needed for its operation, and secondary, or mass memory units, which store larger amounts of data.[4] The information stored in a processor's primary memory must be accessible at a speed that matches the processor's own operations. For the past 25 years, magnetic core has been the principal primary memory technology, but microprocessors now use LSI memory chips for primary storage (see *Table 2-2*). LSI memory chips currently cost $1 to $2 per 1,000 bits. At this price, a 16,384-bit memory chip (designated in technical jargon as a

"16K" memory) costs about $20 to $30. One such LSI memory chip can store all of the alphanumeric characters from one double-spaced typewritten page or one 24-line graphic terminal display. LSI memory could also be used to store a television picture at the television receiver—a device known as a *frame-grabber*—but the cost of such a device today would be several thousand dollars.[5]

Table 2-1
The Evolution of Microprocessors

Microprocessor Characteristics	1972	1978	Estimated Early 1980s	Estimated Late 1980s
Components per chip	5,000	18,000	60,000	› 100,000
Component dimension (millionths of a meter)	10	4	2	1
Speed (million instructions per second)	.1	1	4	› 10
Cost per logical unit or "gate" (in cents)	5	1.5	.4	.04

LSI memory costs are dropping even more rapidly than those of microprocessors, so that one expects to see LSI memory chips available in the early 1980s for 30 cents per thousand bits or less. Further projections are more speculative, of course, but most industry sources expect that well before the end of that decade, LSI memory chips will cost less than 10 cents per thousand bits.

Secondary, or mass storage units hold the greater quantities of information that computer systems draw upon for data processing or information retrieval. Names and phone numbers in a telephone directory, payroll accounts, spare-parts inventories, and airline reservations illustrate the kinds of data found in mass storage units. Mass storage need not have the access speed of primary storage, but the memory units should be cheap and reliable.

Costs vary with the mass memory unit's size and speed of access. Magnetic disc memories, which are in common use for airline reservation and similar information-retrieval functions, store more than one billion bits at a current cost of around 4 cents per 1,000 bits, with retrieval times of less than one-tenth of a second. Magnetic tape memories store larger amounts of data at less than one-hundredth of the cost, but with slower access times of several seconds. Consequently, magnetic tape memory units are more appropriate for less urgent tasks, such as payroll preparation or inventory management, than for "real-time" information-retrieval applications.

Magnetic discs, drums, and tapes are today's principal mass storage media and will remain competitive for many years.

Table 2-2
Digital Storage Technologies

Function and Capacity	Principal Technologies 1978	Principal Technologies 1985
Primary computer memory units (10,000 to 1 million bits, 1 microsecond access time)	(1) Magnetic core (2) LSI circuits	(1) LSI circuits (2) Magnetic core (3) Charge-coupled devices
Rapid-access mass memory units (more than 1 million bits, .1 second access time)	(1) Magnetic drum (2) Magnetic disc	(1) LSI circuits (2) Magnetic bubble devices (3) Charge-coupled devices (4) Magnetic disc
Large, inexpensive mass memory units (more than 1 billion bits; several seconds access time; $.01 per 1,000 bits)	(1) Magnetic tape	(1) Magnetic tape (2) Optical devices

Magnetic tape cassettes and small magnetic disc units (termed *diskettes* or *floppy discs*) are now manufactured to provide secondary storage units appropriate for small computer systems and intelligent terminals. However, other technologies now under development seem likely to displace these rotating magnetic devices for many applications in the next decade.

Magnetic bubbles and charge-coupled devices, as well as LSI memory chips, are the principal competitors for read-and-write memories. Magnetic bubble devices contain tiny magnetic regions that can be created, destroyed, and moved about in a garnet-like material. Charge-coupled devices store and transfer information as a series of electric charges within a semiconductor chip. These technologies will compete on the basis of cost, access speed, and reliability. Magnetic bubble devices also have an additional advantage of retaining information even if the external source of power is removed. Consequently, bubble memories provide data security in the event of electrical generating failure or other power losses.

Optical readout devices also appear promising for low-cost, slower-access mass storage. At present, optical storage devices are used only for large, specialized applications. But the new optical storage media, such as videodiscs, will have more general uses. Although educational and entertainment programming seem the principal initial markets for videodiscs, they can also be recorded with digital data for computer processing instead of analog signals for video playback. Costs are projected to be competitive with, or lower than, the cost of magnetic tape storage by the early 1980s. RCA and the Digital Recording Corporation,

among several companies, appear optimistic about the uses of videodiscs for digital data storage.

Input and Output Devices

The equipment to move information in and out of computer systems is also improving in performance and cost, but at a far slower pace than microprocessors and memory units. Input and output devices dominate the cost of intelligent terminal equipment linked to teleprocessing systems. And as new users of teleconferencing or computer time-sharing services soon discover, many problems remain in effectively communicating with information processing sytems. These human-factor problems will continue to place limits on the widespread acceptibility and use of computer systems throughout the 1980s.

Input devices. The typewriter keyboard or its equivalent provides the usual way to enter data into a computer. Some low-cost systems have tried to develop data-entry procedures using push-button telephones or special equipment with fewer keys than a typewriter. In principle, a 12- or 16-key device with special "shift" or function keys to generate additional characters can handle input requirements. However, these methods have often proved confusing and difficult for the unsophisticated users for whom the low-cost devices were specifically designed.

For some applications, such as pay-television and viewer responses to multiple-choice questions, a simple terminal with fewer push-buttons will serve adequately. Warner Cable is currently experimenting with a five-button terminal for pay-television, alarm services, direct ordering of advertised merchandise, and some simple interactive games. However, this kind of device is too limited for sending messages or for most information-retrieval services.

The typewriter keyboard or its equivalent thus remains the standard input device. Standard keyboards cost product manufacturers about $50. Since typewriter keyboards are a mature electro-mechanical technology that has already passed through many generations of product improvement, costs are unlikely to decrease significantly in the future. Some manufacturers are experimenting with lower-cost, lower-quality keyboards for home computer systems, but their acceptance by consumers remains in doubt.

Other technical approaches for entering information are available at higher cost. These include facsimile scanners, optical character-recognition devices, magnetic-ink recognition devices (used to process bank checks), and code sensors (used for point-of-

sale transactions). Devices more suitable for inexperienced users include screens and tablets that respond to the touch of a finger, or to a pointer or light pen. Such devices have been used experimentally for many years and are available in military display terminals and other high-cost equipment. They may become practical for low-cost commercial devices in the 1980s.

The most important technical breakthrough in input equipment would be an inexpensive, reliable, voice-recognition device. Most users would find speaking a far easier and more convenient way to issue commands and enter information. Speech-recognition equipment is under development in many laboratories throughout the world, and a few simple systems are now used for such routine operations as stopping and starting luggage conveyors at airports.

The pace of development suggests that more applications of voice recognition for the control of machines and equipment will soon be commercially feasible. A device for voice *identification* (for example, ensuring that a person making a financial transaction is authorized to do so) can be anticipated in the 1980s. A "voicewriter" that can provide acceptable rough draft copy from voice dictation seems a likely prospect by 1990. One cannot yet estimate when voice-recognition devices will be cheap and reliable enough for computer time-sharing or home terminal applications. However, this is one area where rapid technological development could bring about significant expansion and as yet unforeseen uses of computer/communications systems.

Voice and soft-copy output devices. Information is received from a computer system in three basic forms: (1) voice (or other audio) responses, (2) soft-copy (nonpermanent) visual displays, and (3) hard-copy records. Voice response is the cheapest and easiest way to send uncomplicated messages to large numbers of persons, because it requires only the ubiquitous telephone at the user's premises. Voice responses are generated from either prerecorded or electronically synthesized words combined under the computer's control. Equipment of both types is commercially available, and voice response is commonly used today for services that need only a push-button telephone for data entry—computer-based stock market inquiries, credit checks, and changes in telephone listings are three examples. Many new uses will emerge as computer-based mass storage systems become cheaper and accessible to more people. However, voice response has obvious limitations and is less desirable than displays or hard-copy output for most applications.

The simplest kind of soft-copy output is a single-line display of a few numbers or letters using light-emitting diodes (LEDs) or

liquid crystals, such as those built into hand calculators. For a few dollars, these displays can be added to an "intelligent telephone" or to any other device containing a microprocessor. Much more versatile is the cathode-ray tube (CRT) which forms the heart of today's TV receiver and the standard computer-display terminal. The CRT's capacity for displaying a changing image or multiple lines of alphanumeric characters is well-known. Small CRTs can now be built for less than $50, but significant cost decreases in the future seem unlikely for this highly mature technology which already enjoys large economies of scale.

The principle technological change in this field in the next decade will be the replacement of CRTs by flat, solid-state panels for both alphanumeric and image displays. Flat display panels do not have the inherent size limitation of CRTs and should therefore lend themselves to large-screen television receivers as well as portable computer terminals. Image quality will also be considerably better than that provided by the current large-screen television-projection devices.[6]

Several different technologies are presently in contention to succeed the cathode-ray tube:

- Plasma (gas discharge) panels that contain an inert gas between two transparent plates. A voltage applied between the plates discharges the gas and produces a bright spot.
- Light-emitting diodes which use the same semiconductor materials as those in calculator and digital watch displays. They emit light when an electric current is applied. Building a large screen with individual LED elements would be too expensive, but methods of producing LED arrays as a single unit are under development.
- Liquid crystals, also used for calculators and watches, inserted as a thin layer between two glass plates. When exposed to an electric field, liquid crystals reflect rather than emit light and hence can be viewed in brightly lit areas.
- Ferroelectric ceramics, materials whose reflective indices for polarized light change with an applied electric field.
- Electroluminescent materials, which emit light when excited by an electric field.
- Magneto-optic films, which deposit on a grid of conducting wires scatter light selectively when current pulses are applied.

It is too soon to tell which of these technologies will be successful, or when. All are being pursued vigorously in various laboratories. Plasma panels have been manufactured commercially, but the costs are still too high to compete effectively with CRTs. Well before 1985, however, most industry observers believe that solid-state flat panels will gradually begin replacing CRTs in computer-display terminals. Introduction will begin with the high-priced, top-of-the-line equipment and spread gradually to lower-cost displays. By the end of the decade, some portable, battery-powered computer terminals should also be commercially available, but low-cost, portable terminals suitable for the home are not expected before 1990.

Unless there are technological breakthroughs or dramatic cost reductions, flat panels are not expected to make serious inroads into the home television receiver market before 1990. Large-screen, flat-panel television receivers should begin to appear on the market in the mid-1980s, but the costs of such receivers seem likely to remain well above $1,000 thoughout the decade. This will place them beyond the reach of the mass market but available for business, commercial, and government users. Like the manufacturers of videoplayers and videorecorders, the producers of large-screen, flat-panel television receivers will face a chicken-and-egg problem in building sufficient consumer demand to realize economics of scale and low-cost production. Thus, CRTs, with their low production costs and large investment in manufacturing facilities, seem likely to retain their place in the television set throughout the next decade. Many new television receivers will contain microprocessors, however, enabling their use as information-display devices.

Many laboratories are also developing holographic and other technologies for three-dimensional displays. Without new breakthroughs, however, there is no indication that three-dimensional displays will be available except for military and special-purpose applications in the next decade.

Hard-copy output devices. Devices that can produce permanent, hard-copy records seem inherently more bulky, expensive, and complex than soft-copy display screens. Hard-copy equipment must store ink and paper, they use more power, and their electromechanical components are noisy and prone to failure. Technological advances will reduce, but not eliminate these problems.

Impact printers, which typically use a mechanical typeface to strike an inked ribbon, will probably remain the dominant technology for hard-copy computer terminals in the 1980s. A

number of advances in impact printing have been made in recent years, such as replacing individual type elements with a printing ball, wheel, or pin-like matrix; but it is not clear where the technology goes from here. Although product improvements will undoubtedly be made, costs seem unlikely to drop substantially from present levels.

Nonimpact printing technologies promise greater gains. These include ink jets which are deflected by electric fields to form characters; xerographic and other electrostatic processes; electrochemical processes; thermal processes, possibly including lasers; and photographic processes. Of these, ink-jet printers should gain popularity for high-speed serial printing of characters. New xerographic printers, using lasers to expose the paper, will be used for high-speed character and image (i.e., facsimile) printing. Thermal matrix devices will be used for low-speed, low-cost printing, while some current electromechanical and thermal printers may remain competitive for low-usage facsimile and similar applications. However, thermal and electrochemical devices are limited by their need for special paper and their generally lower quality of print.

Despite occasional newspaper accounts of a facsimile printer using standard paper for under $200, industry sources do not expect such an advance. Some new printers might be available in the next decade at two or three times that price, but even that possibility remains speculative. Generally, forecasts of technological advances for hard-copy printers are less optimistic than those for displays, memories, and other information system components.

Computer Influences on Telecommunications Systems and Services

This review of computer technology trends suggests that computer developmentss will strongly influence the technical evolution of telecommunications systems and the communications services they offer. The following are several specific examples:

The Substitution of Information Processing for Transmission

With the rapidly falling costs of LSI microprocessors and memory units, it has become profitable to make more efficient use of transmission lines by processing information *before* it enters the communications network. This has been done for some years in the transmission of voice conversations over

undersea cables, where bandwidth is at a premium. People do not talk throughout every second of a telephone call. Electronic equipment at the cable terminals can sense the natural pauses amd gaps in conversations and can interleave segments of other calls within these gaps. Callers think they have a full circuit to themselves, but in fact the channel is shared with others. This is called *time-assigned speech interpolation*, or *TASI*.

Packet switching of data and messages again illustrates the substitution of information processing for transmission bandwidth. If two people have information to exchange, one ordinarily places a call to the other, and a circuit is established between them. They then transmit voice conversations or data between the two points. Usually, however, the circuit is not used to its full capacity. A more efficient approach is to divide the information into a group of bits or "packets" at the terminal. The packets are then shuttled through the network under computer control until they reach their destination and are decoded. Transmission generally takes less than a second, and at no time is there a physical circuit established directly from the sender to the receiver. Packet switching requires a microprocessor and memory at each terminal and a series of computer switches to route the packets along. But even at current prices, packet switching is cheaper than circuit switching for many data applications.

The Trend toward Digital Communications

Computer systems operate with digital bits, whereas telecommunications networks were designed to carry voice signals in analog form.[7] Voice and other analog signals can be coded for digital transmission using pulse-code modulation (PCM) or similar techniques. The LSI technology makes analog-to-digital conversion cheaper, and encourages more direct digital communications traffic. As a result, this technology has accelerated the trend toward installation of digital communications facilities that began in the Bell System in 1960. Still, because of the large existing investment in analog plant, the U.S. switched telephone network will remain a mixture of analog and digital facilities throughout the 1980s.

Increased Mixing of Voice, Data, Message, and Image Communications

After analog signals are converted into digital bits, they can be combined with other digital traffic for more efficient transmission. Interleaving bits from multiple users also provides greater privacy and security, as well as economic advantages. However, it

complicates matters for accountants and regulators who want to separate the costs of the various services.

The Integration of Information Processing and Communications Functions

State-of-the-art electronic switches and data terminals already have information-processing capabilities, and equipment built in the 1980s will incorporate increasingly greater computing power. From a technical standpoint, communications and processing functions should often be combined—as, for example, in terminals providing remote access to information files or switches that can be programmed to provide data-processing services. Again, these technological changes will cause problems for regulators, who want a clear division between "data communications" and "data processing." Technology will blur this distinction even more in the future.

Evolution of Communications Terminals

Designers can program a microprocessor for particular applications, rather than build specialized and expensive hardware for every new function. Among other functions, a microprocessor in a communications terminal can convert signals to a form more suitable for transmission, reduce redundant information to save transmission-channel capacity (bandwidth compression), process incoming signals to derive the desired information and check for errors, and serve as a local computing center. Some of these features are described in the following section.

Communications Terminals

This section discusses the evolution of communications terminals and related equipment for sending and receiving information over communications channels. I first describe terminals used primarily in an office or institutional environment, and then those that will be used in the home. One straightforward but oversimplified distinction between the two is that home terminals should cost less than $1,000, whereas office terminals generally are more expensive.

Office Terminals

By the early 1980s, microprocessors will be routinely incorporated into many office typewriters, copying machines, and facsimile devices, as well as into virtually all data terminals and

private switchboards (PABXs). These machines will have communications connections to central computers, information data bases, and similar equipment in other locations. Thus, a large number of the business letters, memoranda, and other documents that are now mailed will be sent over communications lines between offices within a building or across the country. Distribution time will decrease from hours (within the same business location) or days (among geographically dispersed locations) to seconds or minutes, and will no longer be a function of distance.

This network of intelligent office machines linked by communications lines is often referred to as the *automated office* or the *office of the future*. Four generic types of devices suggest the evolution of today's office machines into the more powerful, integrated systems of the 1980s. These devices are the word processor, the intelligent data terminal, the intelligent copier, and the computer-based PABX.

Word processors. The evolution of the typewriter into an intelligent word processor is the key step in the development of the office of the future. Word processors contain a microprocessor and associated memory,[8] a keyboard, a printer and/or graphic display, and an interface to the communications network. A draft letter or report typed on the keyboard is stored as a series of bits in the word processor's memory. When the draft has been proofed by the writer, these bits can be transmitted to a central storage location, or they can be sent to a colleague, supervisor, or editor for review. That person can then call up the draft for display on his or her graphic terminal[9] (or, if necessary, receive a printed copy), electronically revise and edit the draft on the graphic terminal, and then send the revised draft back to the writer.

When the draft is considered ready, it can be printed locally at the writer's word processor, sent electronically to a central facility for storage or distribution, or transmitted over communications lines directly to recipients in the next office or at a distant location. This process bypasses not only the U.S. Postal Service, but also the internal mail-distribution systems at both ends. A word processor can also print documents that were prepared in some other location and transmitted to it electronically. Each word processor will have a unique address for sending and receiving material.

The main advantage of an interconnected network of word processors linked to computers, information files, and other devices is that it avoids the costs and delay associated with paper handling. A document is entered on the keyboard only once. It can subsequently be retrieved from digital storage for revision or

distribution. Final recipients can view the copy on their terminal displays without any physical document distribution. Paper copies will be made only when and where needed. A word-processing system also allows the writer to incorporate up-to-date information into a document at the last possible moment. For example, one can draft a letter referring to the current month's financial report and then have the most recent data recalled from the computer and inserted into the letter just before transmission.

Precursors of word processors (such as the IBM-MTST) were built more than a decade ago for use in preparing similar letters to multiple addresses. Many varieties of keyboard terminals linked to computing systems are available today and widely used for text editing and information retrieval, as well as for computation. They typically cost $2,000-$10,000, and most do not contain microprocessors. The technical trends ensure that intelligent word processors will be available much more widely and at lower cost in the 1980s. Some manufacturers and consulting groups estimate that over 50 percent of all office documents will be prepared with word processors by 1985.

Intelligent data terminals. Most computer terminals are now used for data entry and retrieval, rather than for word processing. The same technical trends described above will make data terminals less expensive, more powerful, and largely indistinguishable from word processors. The decreasing costs of microprocessors and storage will encourage more data processing at the terminal, without communicating with a central computer. At the same time, computer users will routinely have access to remote information bases and computing facilities.

Over the next decade, more and more work stations will have a graphic or printing terminal available for local processing or storage, for data entry, for text and data editing, and for information transmission. The price of a simple terminal with a keyboard and display, a microprocessor, and associated memory is already below $1,000.

Intelligent copiers. While word processors can print letters, memoranda, and short documents directly at the recipient's work station, large offices will need faster printers for long documents and multiple copies. The evolution of today's copying devices into "intelligent copiers" will occur with the addition of a microprocessor and memory unit, a multiple-font character generator, and an interface to the communications network. By 1990, intelligent copiers are likely to dominate markets presently filled by offset presses and duplicators, photo-composition equipment, and stand-alone office copiers.

The intelligent copier will still perform its present function—making multiple copies of physical documents brought to the machine. But it will also be able to prepare copies from digital data, using an internal character generator and a laser-imaging system. The type font, spacing, and format of the printed output would be selected by instructions in the incoming data or by the copier's operator. Thus, documents stored in the computer memory could be transmitted to the intelligent copier and printed there for local distribution. Or a memo prepared in one city could be sent electronically to another for printing and distribution.

Intelligent copiers may also incorporate facsimile scanners that use bandwidth-compression techniques to reduce transmission time. Most facsimile devices today scan an entire page and transmit each light and dark element--an inefficient and costly approach. In contrast, an intelligent copier would be able to store the bits representing each element and transmit only the changes between light and dark areas. A further step would be to include logic in the copier, so that it could recognize characters on a printed page and transmit bits describing the character, rather than its individual light and dark elements. This capacity would reduce the data-transmission requirements by a factor of more than ten, as well as improve the quality of the output document. Of course, the need for character recognition would be avoided if the document were initially stored in digital form. Facsimile transmission will be used principally for documents containing handwriting, graphics, or other nonstandard characters.

Intelligent copiers are under development by Xerox, IBM, Hewlett-Packard, and a number of other manufacturers. They should be on the market well before 1980 and comprise the bulk of new copier sales within the decade. In combination with word processors and mass memories, intelligent copiers will replace much of the present physical storage and transmission of documents.[10]

Computer-based PABXs. In the 1980s, businesses will increasingly intermix voice, data, text, and message information on the same communications lines. An intelligent, or computer-based, PABX will control these information flows. A computer-based PABX can have additional logic and memory units built in at little extra cost to provide capabilities for information processing and local storage, as well as the traditional PABX functions of switching, routing, and line control. In addition, computer-based PABXs offer a variety of additional communications services as part of their standard design. These include call-forwarding, conference-calling, and call-waiting (signalling a busy line when another call is waiting). A list of the features presently provided

by AT&T's Dimension computer-based PABX is shown in *Table* 2-3.

Computer-based PABXs are available today from AT&T, GTE, Northern Telecom, IT&T, IBM (currently offered in Europe only), and several other manufacturers. More powerful versions will be the standard office communications switching systems of the 1980s.

Table 2-3
Selected Optional Features of the AT&T Dimension PABX

Basic Optional Features	
Attendant position, alphanumeric display	Provides a visual display on an attendant's console of the four symbols used to identify the calling number, etc.
Call-forwarding	Automatically routes to a designated extension either all calls or all calls directed to an extension that is busy or does not answer.
Call-hold	Allows use of a code to hold an ongoing call while originating another call or feature.
Call-pickup	Allows use of a code to answer calls to other extensions within a present pickup group.
Call waiting	Automatically holds calls to a busy extension while the called party is signalled that a call is waiting.
Outgoing trunk-queuing	Provides automatic queuing of calls when all trunks are busy and automatic ringback when a trunk is available.
Three-way conference transfer	Allows an extension user to dial in a third party while the second party is held; the user can also hang up or drop the third party from the call.
Additional Centrex and Deluxe Business Features	
Automatic callback	Automatically connects an extension to a previously busy number once the line becomes idle.
Automatic identification	Automatically identifies extensions on outgoing calls in order to permit direct billing to extensions for toll calls.
Code restriction	Limits the office and area codes that can be dialed from certain extensions.
Direct inward-dialing	Allows direct dialing to extensions from the dial network without attendant assistance.
Loudspeaker paging	Provides access to voice paging equipment for attendants and extension users.
Remote access to PBX services	Allows a user calling from outside the PBX to access the PBX services via an exchange-network connection.
Tandem tie trunks	Permits a caller at a distant PBX to direct dial tie trunk calls through the switching system.
Trunk-to-trunk connections	Allows an incoming or outgoing trunk call to be extended via the attendant to another outgoing trunk.

Source: AT&T.

Interconnection of office terminals. As discussed above, the elements of office communications systems of the 1980s exist today and are used for text editing, information retrieval, and data communications. A few organizations, such as New York's Citibank and the Hewlett-Packard Corporation, are tying terminals together in a deliberate effort to replace paper flows with electronic document storage and distribution. The Hewlett-Packard network now handles more than 20 million messages annually among the numerous company locations.[11] By the early 1980s, interconnection of word processors and other terminals within large commercial and government organizations will be routine.

The next step is to interconnect terminals in different organizations. Many research-oriented institutions already have such links through packet-switched networks, such as the ARPANET and Telenet, or through computer time-sharing services, such as TYMNET. Sending messages among terminals—either as part of a formal, computer-based teleconferencing service or as informal "computer mail"—has emerged as a significant use of these systems (as well as a popular pastime) in the past few years.

As another example, an academic colleague in Los Angeles recently prepared a short paper for submission to a professional journal. The paper was to be sent to an editor in Montreal for review. As is often the case, the author wanted to make some last-minute changes in the draft just before the final deadline date. Consequently, rather than mailing the revised draft to Montreal, he had it keyed into the university's computer system in Los Angeles and transmitted over telephone lines to Montreal, where it was stored and available for display or printout at the editor's terminal. But because the editor was in London at the time, his secretary entered a new address and sent the text via either satellite or undersea cable to a London computer. The editor called up the text for display in London, suggested a few editorial changes, and then transmitted the revised text back to the author in Los Angeles. The editor's suggestions were noted, revisions were made, and the final manuscript was again sent electronically from Los Angeles to Montreal, where it was ready for journal publication. The entire process took less than 48 hours.

Today, this kind of electronic text processing is available to a relatively few sophisticated users of teleprocessing systems. But the number of such users is growing steadily as technology develops less expensive terminals, storage facilities, computers, and transmission channels. By the early 1980s, direct terminal-to-terminal communication will be widely used by most major

businesses and by some professionals in their homes. It will have made serious inroads into business use of Telex message services. By the late 1980s, the costs of word processing and message transmission should be sufficiently low to make it attractive to nearly all businesses, large and small.

The costs of electronic message transmission are difficult to estimate because they depend on the number and length of the transmitted message, and on communications tariffs rather than underlying costs. A recent study by Raymond Panko estimates that in 1975, the average cost of sending a 50-word message electronically was about $1.20, made up in roughly equal parts of computer costs, labor costs, communications costs, and terminal costs.[12] Panko projects that the cost will fall to between 25 and 52 cents by 1985. The marginal cost per message will be much lower—perhaps only a few cents—in heavily utilized systems. Even at 50 cents per message, electronic terminal-to-terminal transmission appears a ready substitute for much first-class business mail.[13]

Terminals for teleconferencing. Intelligent terminals in the office will also lead to some substitution of telecommunications for face-to-face meetings. It is by no means clear to what extent telecommunications may reduce travel, either business or personal; but teleconferencing services are expected to grow significantly in the energy-conscious society of the 1980s.

Teleconferencing requires a choice of communications modes: audio only, audio and graphics, messages, or video. Telephone conference calls have been available for some years, of course; but computer-based PABXs and computer-controlled central office switches make them easier to set up and operate. Loudspeaker telephones usually suffice as terminals, although more elaborate audio-conferencing equipment has been designed.

A recent paper by Pye and Williams reports that audio conferencing alone is suitable for 22 percent of business meetings that are currently conducted face-to-face. Adding graphic transmission capability would make teleconferencing suitable for an additional 17 percent of business meetings.[14] Text and other alphanumeric materials can be exchanged using the graphic terminals that will be widely available in offices in the 1980s. Special equipment for transmitting handwriting and other graphics will also be commercially available, but the demand for these services is uncertain.

Teleconferencing by exchanging messages under computer control (computer conferencing) represents a different approach. Participants in a computer conference need not be physically available at the same time; instead, they can enter messages on

their terminals and read those of other participants whenever it is convenient. Messages are stored at a central computer, so that a participant can call up the conference file for display or printout at his/her terminal, then respond with individual messages or general comments to all participants. Although computer conferencing presents some problems (particularly for uninitiated terminal users), it is a useful means of communication for busy people at geographically dispersed locations.

Videophone and other switched video services. AT&T's Picturephone was one of the great marketing disappointments of the past decade. The Bell System introduced commercial Picturephone service in 1970, while other telecommunications companies in the United States and abroad hurried to develop their own switched video systems. But at the prices that must currently be charged to recover costs, there has been little demand for video telephone service. Technology will reduce the costs of switched video service over the next decade, but it remains doubtful whether video telephones will achieve commercial acceptance during the 1980s.

The principal technological advance is the availability of inexpensive digital logic and memory units in the videophone terminals, allowing signal processing and storage to reduce transmission requirements. Picturephone was originally designed with a roughly 5-inch-square display that required a bandwidth of about 1 Megahertz (MHz), or a digital data-transmission rate of about 5.6 million bits per second (Mbps).[15] Using bandwidth-compression techniques which transmit only those picture elements that change in time (i.e., the moving areas), Picturephone can be transmitted at 1.5 Mbps without noticeable degradation. This is a significant improvement because it allows transmission over the standard T-1 digital channels installed throughout the telephone network.

Further bandwidth reduction is feasible, but only with some reduction in the quality of the moving image. By 200 Kbps, blurring of the lips and other moving areas becomes noticeable. At 56 Kbps (the transmission rate for a digital voice channel) displaying a continuous moving picture is no longer feasible. Instead, individual frames can be stored and displayed every few seconds, like a series of snapshots. This is sometimes known as *slow-scan* video.

Bandwidth compression requires extensive storage capacity at each terminal. When Picturephone was developed in the 1960s, full-frame storage was too expensive for bandwidth compression to make economic sense. In the 1980s, the cost of LSI or magnetic-bubble storage should be low enough for compression

to become economically advantageous. Charge-coupled-device cameras should also reduce the costs of the video terminal.

Technology thus offers a range of potential switched video services with different terminal and transmission requirements and different costs. But the experts do not agree on which, if any, of these services will be marketable. Based on the past experience with Picturephone, some contend that subscribers will demand full television quality and will not accept a smaller, head-and-shoulders display. AT&T is no longer actively marketing Picturephone as a switched video service to individual terminals. Instead, it now offers Picturephone Meeting Service, which uses two-way television transmission among meeting rooms in selected cities. The cost for a three-minute connection between New York and San Francisco is $19.50, which makes the cost of a one-hour video call roughly equal to the round-trip air fare not counting the value of the traveler's time. Other two-way television links between meetings rooms have been established by large companies and government agencies over private lines, but it is not clear that a large demand for this service exists.

Video conferencing could help politicians stay in touch with their constituents and have other important applications in the public sector, but according to Pye and Williams, video adds only 2 percent more to the 39 percent of business meetings suitable for audio and audiographic teleconferencing. And neither business nor residential consumers have yet indicated that they are willing to pay several times the cost of voice communications to see the person at the other end of the call. Consequently, full video service may well remain an expensive, special-purpose service throughout the 1980s.

At the other end of the scale, slow-scan video, oriented toward graphic and document transmission over a standard digital voice channel, may be adequate for most business applications. Slow-scan video terminals could be available in the 1980s in the $1,000 range, and the service would be less expensive and faster than the similar Videovoice service offered unsuccessfully by RCA in the early 1970s. However, the demand for such a service remains uncertain.

Point-of-sale and banking terminals. Several kinds of communications terminals have been designed for remote financial transactions. Among them, the following are all available today:

- Point-of-sale (POS) terminals in retail stores transmit information to a central computer about the goods purchased and the form of payment. With POS terminals, stores can give immediate check and credit authorization, debit or

credit funds in customers' bank accounts, and maintain accurate sales and inventory records. These terminals generally contain a small (12- or 16-key) keyboard for entering the transaction data, a device to read information from the customer's credit card, a small memory unit, a low-data-rate interface to the communications line, and relatively simple control logic. Credit verification is given from the central facility, either by lighting a lamp on the terminal or by telephone voice response. Telephone companies (e.g., AT&T's Transaction telephones) and a number of manufacturers provide POS terminals.

- Automated teller machines (ATMs) provide such banking services as cash withdrawals or advances, deposits to checking or savings accounts, or transfers of funds among accounts, without a human operator. Processing and communications requirements are similar to those of POS terminals, except that the machines must be heavily armored and have reliable and secure electromechanical devices for handling cash. Consequently, ATMs cost 5 to 10 times as much as POS terminals.
- On-line teller terminals (OLTTs) provide direct access to customer records for financial transactions in banks. The OLTTs are much like office data terminals with graphic displays.

There are no real technical barriers to linking POS and ATM terminals into an integrated electronic funds-transfer (EFT) system that would reduce the flow of checks and credit-card paperwork. With more than 15,000 financial institutions and 6 million retail businesses in the United States, EFT terminals represent a large potential market. Substantial legal and political barriers remain, however, that make it difficult to forecast how quickly consumer-oriented EFT systems will grow.[16]

Home Communications Terminals

Discussing the evolution of communications terminals for the home is much more difficult than projecting the developments in office terminals. The same technologies apply, but costs become a far more critical issue. Consumer demand depends on cost, and cost depends on the production volume. The "chicken-and-egg" cliche applied so often to home communications equipment and services is tiresome, but apt. Yet, as hand calculators and digital watches attest, the introduction problems can be overcome.

The "ultimate" home terminal would be used for a wide range of services—message, voice, image, data, and text. The terminal

would have a full alphanumeric keyboard for input, as well as a more easily used key-pad for dialing and frequent instructions. It would provide both hard-copy and graphic-display output. It would store information, send messages to, and receive replies from a distant person or computer. Finally, in John Pierce's words, "the terminal would be as small and light as a portable typewriter. It would cost a couple of hundred dollars and would last forever."[17]

We are still far from building this "ultimate" home terminal, but one can see—cloudily—the technical evolution of at least six generic devices in the home: (1) the telephone, (2) television receiver, (3) typewriters, (4) pay-television terminal, (5) video recorder and player, and (6) the hand calculator, TV game, and home computer.

The intelligent telephone. The 12-key pushbutton telephone can serve as a low-cost intelligent terminal with the addition of a microprocessor and associated memory, a slot for a magnetic card or some other simple data-entry device, and a liquid crystal or LED alphanumeric line readout. Such an intelligent telephone could be available for purchase by home subscribers in the early 1980s for under $200. It would include capabilities for conference calls, repertory dialing, call-forwarding, and other telephone-related features.[18]

Besides telephone-related services, an intelligent telephone would provide access to information and transaction services that do not require extensive graphic or hard-copy output. Credit card and banking transactions from the home are two examples. The Greater New York Savings Bank and a few other institutions now offer these services, using telephone push-buttons for input and voice response for output. However, the necessary data-entry procedures may be too complex for many home subscribers. The addition of a magnetic card reader and an information-processing capability to the telephone would simplify the exchange of information between the home telephone terminal and the central computer. And for financial transactions, a liquid crystal or LED display (similar to that in hand calculators) seems preferable to voice response.

A stock-quotation service providing current prices on individual stocks is another function well-matched to the intelligent telephone and more useful to most investors than the delayed stock ticker offered by cable television systems. The subscriber would call a designated number, enter the appropriate code, and then view the current quotations on the telephone display. In this same way, voice libraries of recorded information—ranging

from emergency first-aid procedures to a dial-a-joke compendium—could also be automatically accessible by telephone.

Many other information services will require more graphic display capability. A small CRT or (later) a flat-panel display providing 8 to 24 lines of alphanumeric characters could be added to the telephone for under $100. Subscribers could also use a modified television set for information retrieval. However, message transmission generally requires a full alphanumeric keyboard, rather than a 12- or 16-key pad.

The intelligent telephone could provide clock and calculator functions in the home, as well as remote control of other home appliances. It could also serve as the input device for a dedicated home computer system that would, for example, monitor and control energy use. Once the microprocessor, memory, and display are built into a telephone, the marginal cost to use them for other applications becomes quite small. However, the cost of sensors, electromechanical controls, and internal wiring will remain a serious barrier to the use of computers for monitoring and control functions in the home.

Television receivers for data processing. The television set is the obvious display device for home communications and information services. With 525-line resolution, a television receiver cannot comfortably show a full page of printed text. It can, however, display several hundred alphanumeric characters—enough for most message and information services. The television set has a full graphic capability. Most important, it is already in the home, so that the consumer need not invest in a separate display.

The cost of adding an LSI chip with memory and a character generator to a television receiver is about $200 today. With volume production, that cost could easily drop to below $20. The first such application in the United States has been the display of television captions for the deaf.[19] In Britain, the BBC and the British Independent Broadcasting Authority are operating similar experimental systems (CEEFAX and ORACLE, respectively) which display news and other information on LSI-modified receivers. The information is transmitted over spare lines of the broadcast television signal and requires no interactive communications from the home.

Subscribers could request a much richer array of information services via telephone lines or a two-way cable television network. The British Post Office is developing its Viewdata system to display data sent over the telephone lines on modified television sets, using the same format as CEEFAX and ORACLE.

Prospective services include specialized news bulletins, current financial data, and other information ranging from community services to recipe files. Field trials are set to begin shortly, with services available to the public before 1980. Technically at least, a similar system could easily be developed in the United States, with add-on costs to the television set of less than $100 (in volume production). AT&T and other U.S. companies reportedly are working on prototype systems, although they have made no public announcements.

Here, as always, one must be careful in moving from technical possibility to commercial likelihood. Television sets are manufactured for entertainment, not data uses. Those who want information and message services at home may prefer to purchase or rent a separate display terminal rather than to modify the household's primary television set. Professionals who work at home would be especially likely to have their own, dedicated display terminals, either paid for by their employers or justified as a business expense.

A display terminal with a full alphanumeric keyboard would cost considerably more than the add-on cost of a modified television set—probably at least $300, even with mass production. But this equipment could also be used as a home Telex terminal to send and receive messages. While no one knows the consumer demand for a Telex-like service, some observers believe it may be the key to breaking the home terminal "chicken-and-egg" barrier in the 1980s. If so, home terminal-to-terminal messages could displace another significant portion of first-class mail services.

Printing terminals for the home. One might expect that the electric typewriter could form the basis for a low-cost home printing terminal, analogous to the evolution of the office typewriter into a word processor. However, this does not appear economically practical in the next decade. Although new concepts are under development, impact or nonimpact printing terminals for the home, with full alphanumeric keyboard, microprocessor, memory, and communications interface, are expected to cost at least $400 to $500 in the mid-1980s.[20] If rented, the monthly charge would be $20 to $30, depending on the appropriate depreciation and maintenance requirements. Some consumers and professionals who work at home would be willing to pay this much to send and receive messages and obtain hard-copy results, but probably the majority of households would not.

Home facsimile terminals also appear expensive and unlikely to be used for the electronic delivery of newspapers, periodicals, and other bulky documents to the home. The cost of paper and

other expendable supplies poses an added barrier, in that printing the equivalent of a daily newspaper in the home would require more than 100 square feet of paper every weekday and nearly 400 square feet on Sunday. Newspapers are now delivered to the door for between one-fifth and one-half cent per page. Costs for home delivery would have to go up by a factor of ten before electronic transmission would become competitive.

Cost comparisons for periodicals and catalogs also greatly favor mail over electronic delivery. Moreover, the full-color graphics extensively used in such publications would prove much too expensive for home facsimile. We must await the invention of a cheap, low-power, hard-copy device using ordinary paper (or one that could recycle its own product) before facsimile terminals will be widely used in the home.

Cable and pay-television terminals. In the 1980s, cable television systems may finally develop their long-awaited capacity for two-way communications for pay-television and other interactive services. If so, the cable/pay television terminal would contain the basic logic and communications elements needed to send data and short messages from the home to the cable system studio or headend. In principle, once a two-way terminal is in the home for pay-television, it could be used for other data, information, and message services as well. In practice, however, these services may already be available over telephone lines by the time two-way cable systems become operational. The cable and pay-television industries also have not developed technical standards for terminals that would encourage their use for other services. Consequently, while it is technically feasible to build a cable television data terminal for about the same price as an intelligent telephone—$100 to $200 with volume production—the cable industry may not evolve in that direction. Rather, cable systems may continue to install less-expensive terminals dedicated to pay-television and a few special services.

Video recorders and players. Reports in the 1970s of the birth of a burgeoning new industry for home video players and recorders proved to be somewhat exaggerated. But industry executives and most outside observers now believe that video recorders and players are ready to take hold and will become major consumer products in the 1980s.

Two technologies—videotape and videodisc—are in contention. Videotape systems can record television programs from the home receiver as well as play prerecorded entertainment or instructional tapes. With a camera added, they also make home video recordings. Videotape equipment has been commercially available for over a decade and has gradually improved in

performance and price. In early 1978, more than 15 companies were selling home videotape systems at retail prices of $1,000 to $1,300 (some older models were available for $800).

Videodisc systems play prerecorded materials for display on a conventional television receiver. They are only now moving toward commerical introduction after a number of false starts. While several technical approaches were developed in the past few years, the leading contenders today are optical videodisc systems that reflect laser light from marks or depressions on a rotating disc onto a photosensor. The MCA/Phillips "Disco-Vision" system is scheduled to be introduced commercially in the United States in late 1978 at a cost of about $600. Other optical systems will likely follow. RCA has indefinitely delayed introduction of its capacitance-sensing "SelectaVision" system, but at least in its public announcements the company remains committed to this alternative videodisc technology.

It is too early to tell whether videodisc systems will gain broad consumer acceptance. Videotape systems, with their recordings capabilities, are more versatile; but both the hardware and recording media are more expensive to produce. In volume production, videodiscs can be made for a dollar or so per playing hour, while videotape costs are several times higher. However, software prices to the consumer will probably depend more on market factors and the cost of talent than on underlying production costs.

Although hardware costs of both systems should decrease over time, cost reductions are limited by the electromechanical subsystems. As a consequence, cost reductions over a 10-year period may be between 25 and 50 percent. Consumers will not see the much larger cost reductions that have characterized such LSI-based products as home calculators and digital watches over the past few years.

Estimates of video player and recorder penetration by the mid-1980s range from 10 percent or less to nearly 50 percent of U.S. households with color television sets. A 25-percent penetration by 1985 would represent about 18 million units. Whatever the consumer response, most observers agree that the instructional and institutional markets for video players and recorders will continue to expand during the 1980s. Optical videodiscs, with their frame-freezing capability, seem favored for prerecorded instructional programming. They may also prove useful for low-cost mass storage of digital data for computer systems.

Manufacturers are expected to extend and improve these technical systems, rather than to introduce wholly new technologies during the 1980s. Toward the end of that decade, a small

magnetic disc—or, more speculatively, a solid-state video memory system—might be developed for consumer use. The magnetic video recorders/players incorporating these technologies could then be more readily adapted to information retrieval and other interactive services that require storing a full frame of television picture information at the terminal *(frame grabbing)*.

Current frame-grabbing technologies—storage tubes, magnetic tapes, and LSI memories—are either clumsy or expensive or both. Although solid-state memory costs will decline dramatically, full-frame storage of more than a million bits is still likely to cost the consumer $200 or more throughout the 1980s. Consequently, unless the frame-grabbing capability is built into an entertainment device like the video recorder/player, it seems unlikely to be purchased alone for home communications or information services.

TV games, hand calculators, and home computers. Hand calculators and TV games represent the first wave of LSI devices in the home. The current generation of TV games are programmable; that is, the logic and display instructions for each game are contained on magnetic tape cassettes or plug-in LSI memory chips. These games now sell for $150 to $300, with additional game cartridges costing $15 to $30. Their costs should decrease over time, following the path of earlier game offerings.

Since TV games are already attached to the home television receiver, the next logical step would be to connect them to the telephone or to a two-way cable television network, so that games could be played with remote opponents. Interactive "Pong" or "Tank," or the more sophisticated games now under development, could have great appeal for remote contests between friends or anonymous opponents. When such games have been introduced on a university computer time-sharing system, their popularity has sometimes overloaded the system and led to restrictions on student use. A principal attraction seems to be the ability to cloak oneself in a pseudonym ("Red Baron" and "Hot Dog" seem to be popular handles) and then aggressively but anonymously challenge the world. Both the attraction and the handles are analogous to the CB radio experience in the mid-1970s.

Technically, adding a communications interface and some additional memory to a TV game to allow interaction is not difficult or expensive. However, problems arise in establishing interface standards so that the games from different manufacturers can talk with one another. Overloading local telephone exchanges represents another potential problem. If interactive TV games became popular, their use could saturate telephone central offices that are designed to handle relatively short voice

conversations. This would be likely to accelerate the telephone companies' efforts to establish "usage sensitive pricing"—that is, charges for individual local calls—which in turn would dampen game players' demand for telephone communications. The probable response of the cable television industry is less clear. In any event, the development of interactive TV games in the 1980s represents a technical possibility whose likelihood will depend on communications pricing and regulatory responses.

Home calculators and computers will also continue to show large gains in price and performance. Computer hobbyists, according to subscriptions to hobbyist magazines, now number over 60,000. Most hobbyists soon run out of pure computing tasks and turn their attention toward exchanging programs and messages, using data bases, and playing games with other hobbyists. Thus, as their numbers grow, computer hobbyists will want to interact with each other over communications lines. Like professionals who work at home, hobbyists will want their own home communications terminals. How large a market computer hobbyists will represent in the 1980s remains speculative. One analogous group of technological hobbyists are ham radio operators, who currently number about 325,000 in the United States.

Fitting the pieces together—home communications centers. Home communications terminals can evolve through any or all of the devices described above. We already have the technology. As one example, a fully assembled computer with LSI memory, magnetic tape cassette for program storage, CRT display, and standard communications interface was introduced in 1977 at a retail price of under $600. No one knows what consumer demand exists for such a product at that price, but it clearly points toward new offerings at lower prices in the next decade.

A conservative view of the consumer products available by the mid-1980s would include the following: (Price estimates indicate relative prices and should not be taken as literal forecasts.)

- For $100-200, an intelligent telephone or cable television terminal for relatively simple data entry.
- For $50-100, television receiver modifications to display alphanumeric information and data.
- For $300-400, a separate graphic display terminal with full alphanumeric keyboard.
- For $400-500, a printing terminal with full alphanumeric keyboard.
- For $300-500, a video player.
- For $500-800, a videotape recorder.
- For $50 or more, additional computing power and memory.

Because these devices contain or use many common elements, including microprocessors, solid-state memory chips, pushbutton or typewriter keyboards, and CRT displays, some experts have suggested that they will be integrated into a single home communications center in the 1980s. One such center, as described by Douglass Cater, is affectionately called MOTHER—for Multiple Output Telecommunications Home End Resources. The home communications center would include a large color television receiver, a videotape recorder and/or videodisc player, programmable television games, timer and calculator, appropriate buttons for pay-television and other services provided over the cable system, and a connection to the telephone. A typewriter keyboard and printer would be optional features.

The home communications center would integrate entertainment, educational, information, and message services at a single station. Adults would watch television for entertainment, record programs, pay bills, scan merchandise catalogs and travel brochures, update the social calendar, and do some work at home. Children would use it for computer-assisted instruction as well as for entertainment and games.

This kind of integrated home communications center does not seem a likely possibility for the 1980s for two principal reasons. First, the center would be too expensive—more than $1,000—to buy as a unit. It seems unlikely that many households would be willing to make that kind of investment in electronic equipment. Second, the primary use of a television display in the home will continue to be for entertainment. Most families appear unwilling to have their primary television set diverted for extended periods to other, nonentertainment activities.

A different view is that these home communications devices will be assembled, component by component, like audio equipment. Microprocessors and memories will be cheap enough to be built into several devices, rather than concentrated in a single communications center. Television sets, TV games, calculators, pay-television terminals, video players and recorders, and data displays will, for the most part, be produced separately. But as the decade progresses, an increasing number of these items will be designed for common interconnection. A central control unit will be developed into which individual devices can be connected. It could very well be a part of the television receiver, as most audio device jacks are built into an audio receiver, or it could be a separate, self-contained unit. The end result may not be as elegant and aesthetically integrated as MOTHER, nor as cheap as John Pierce's "ultimate" terminal, but it appears a more practical way of moving toward enhanced communications capabilities in the home.

Transmission and Switching Systems

Telecommunications has traditionally distinguished between mass communication and point-to-point communication. Technically, mass communication is much simpler. It involves a few sources sending the same signals to a large number of receivers. The sources—radio and television stations, or cable system headends—are often linked by transmission lines to form mass communication networks. *(see Figure 2-1)*

Point-to-point communication implies a two-way exchange of information between individual senders and receivers. As a consequence, the technical plant for point-to-point communication requires complex switching facilities as well as local distribution links (local loops) and long distance transmission trunks. In the U.S. telephone network, local calls are switched by local central offices.

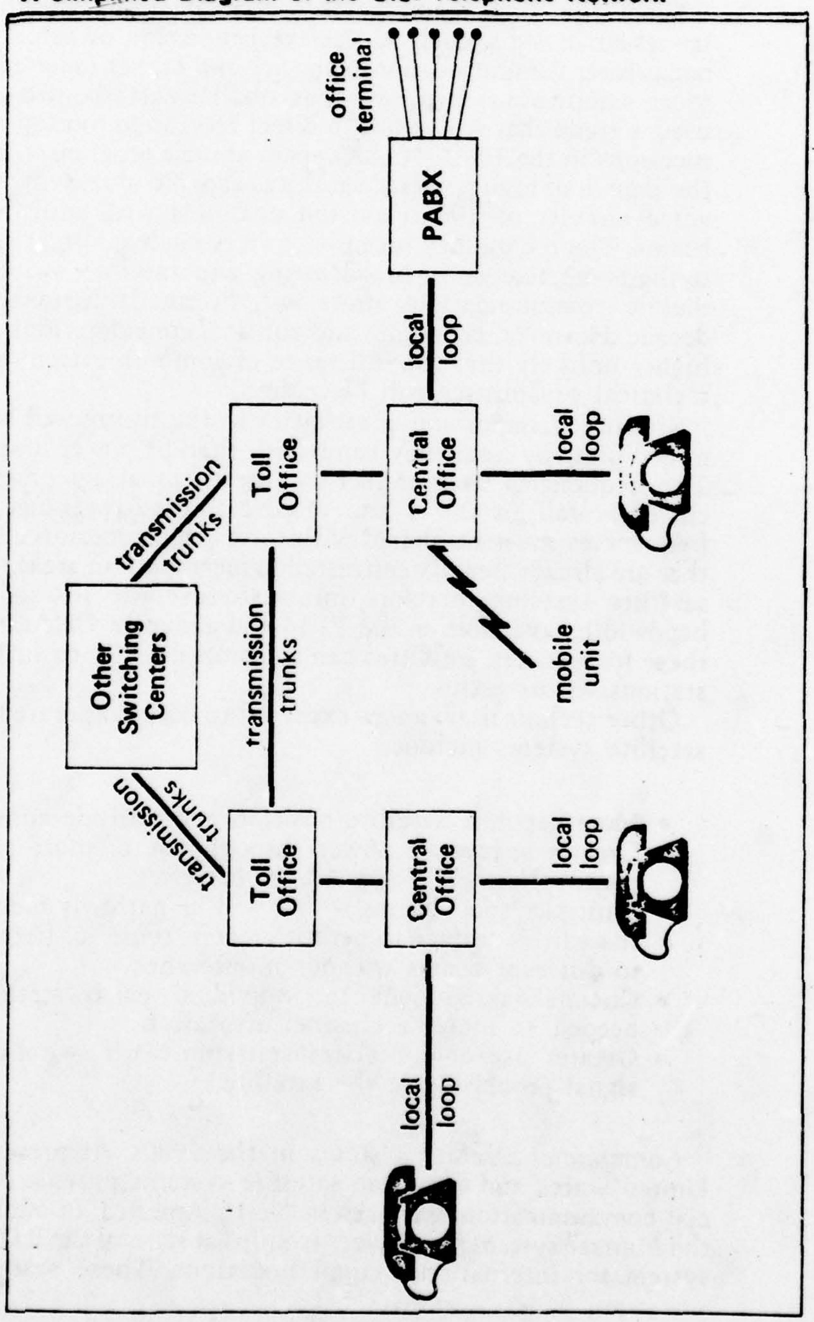
A long distance or toll call is routed from the local central office to a toll switching office, where it proceeds over toll transmission trunks to the switching office nearest its final destination. A long distance call may pass through several toll switching centers on its way to the destination toll office.[21]

Technological advances affect not only the transmission, switching, and local distribution functions but also the relationships among those functions within the telecommunications network. Satellites, for example, can bypass local loops and switching offices to provide direct end-to-end transmission. Moreover, technological change is blurring the distinction between mass and point-to-point communications, allowing each to provide communications services that were once the exclusive province of the other.

Change has been particularly dramatic for transmission technologies over the past 30 years, bringing the commercial introduction of microwave radio, coaxial cable, and communications satellites. These advances have been reflected in lower prices for long distance calls, but only partially; this is because switching, distribution, and terminal costs have not fallen so rapidly, and because regulators have used long distance revenues to subsidize the costs of local telephone service.

In the 1980s, technology will bring more transmission capacity and more choice of transmission modes. Mass communications will see the development of direct-broadcast satellites and optical fibers for television transmission. For point-to-point communication, new satellite systems and optical fibers will compete with improved versions of today's wire, coaxial cable, and microwave transmission systems.

Figure 2-1
A Simplified Diagram of the U.S. Telephone Network



Communications Satellites

Since the first commercial communications satellite was launched in 1965, each successive generation of satellites has had greater communications capacity and higher radiated power. More satellite power means that smaller earth stations can be used, a trend that will result in direct rooftop-to-rooftop communications in the 1980s. NASA's space shuttle program will permit the launch of high-powered satellites capable of relaying 100,000 voice circuits or 100 television channels with multiple spot beams. The technology for new services such as direct satellite-to-the-home television broadcasting and satellite switching of mobile communications units will be available in the next decade. However, economic and political considerations make it highly unlikely that the full range of communications satellite technical capabilities will be realized.

Satellite transmission capabilities in the future will be determined more by frequency bandwidth than by power limitations. The frequencies used are set by international agreements and currently fall in the 4 and 6 GHz microwave range. These frequencies must be shared with terrestrial microwave services that are already heavily congested in metropolitan areas.[22] Future satellite systems therefore intend to use the less congested bandwidths available in the 12-14 and above-18 GHz ranges. At these frequencies, satellites can transmit directly to small earth stations within cities.

Other technical advances expected to be incorporated in new satellite systems include:

- More accurate satellite position and attitude control.
- Greater spacecraft power through use of more efficient photovoltaic cells and storage batteries.
- Multiple "spot" beams which will be narrowly focused on the earth's surface to permit greater "reuse" of frequencies in different beams without interference.
- Channel assignment to individual earth stations, as needed, to increase channel utilization.
- Greater use of digital transmission, with switching and signal processing at the satellite.

Commercial satellite systems in the 1980s. At present, four United States and Canadian satellite systems provide commercial communications services in North America, in addition to the Marisat system for services to ships at sea and the INTELSAT system for international communications. These systems are

owned by Telesat Canada Corporation, Western Union, COMSAT General (for AT&T/GTE), and RCA. Their technical characteristics are compared in *Table 2-4.*

Table 2-4
North American Communications Satellite Systems

	Telesat "Anik"	Western Union	RCA	COMSAT General (AT&T/GTE)	Satellite Business Systems
Operational date	January 1973	July 1974	February 1976	June 1976	Planned for early 1981
Number of satellites planned in orbit	3	2	3	3	2
Channels per satellite	12	12	24	24	10
Channel bandwidth (MHz)	36	36	34	34	43
Channel capacity when used for: one-way voice channels	960	1,200	1,000	1,200	1,250[a]
data (megabits per second)	45	45	45	45	43
television channels	1	1	1	1	..
Frequency (GHz)	4/6	4/6	4/6	4/6	12/14
Earth station size (meters)	4.7-30	15.5	4.5-10	30	5-7

Note: (a) Using 32 Kbps per voice channel.

An important new development will be the scheduled launch in 1980 of the first satellite built by the Satellite Business Systems (SBS) consortium, composed of IBM, COMSAT General, and Aetna Insurance. Incorporating most of the technical advances described above, the SBS satellite is designed to operate at 12-14 GHz, with rooftop earth stations 5-7 meters in diameter. The SBS system points the direction for other new satellite systems of the 1980s.

The INTELSAT consortium will expand its international communications capacity through a new generation of satellites (INTELSAT-V) introduced in the early 1980s. Unless political factors change, the INTELSAT system seems likely to remain oriented toward large earth stations tied into national telephone systems, even though some users might prefer small earth stations located at their sites.[23]

Broadcast station and cable system networking. Distributing television programs to commercial networks, the public television system, and independent stations was seen in the 1960s as an initial application for a U.S. domestic satellite system. In recent years, however, AT&T and other carriers have reduced their tariffs for terrestrial video transmission, so that the television networks have not moved to satellite service. Satellites now primarily interconnect cable television systems. Home Box

Office, the nation's largest pay-television syndicator, leases circuits on the RCA satellite system to distribute pay-television to about 100 earth stations serving cable television systems throughout the country. Another firm, Southern Satellite Systems, distributes programming from an independent television station in Atlanta, Georgia, to cable systems in the Southeast.

More regional and national television networking via satellite should occur in the next decade as satellite capabilities expand and the costs of earth stations drop. In early 1977, the Federal Communications Commission authorized the use of 4.5 meter earth stations instead of the 9 meter stations previously used for television reception. This has reduced earth station costs from roughly $100,000 to under $40,000, making satellite reception economically feasible for most cable systems with more than 1,000 subscribers. The Public Broadcasting Service has contracted with Western Union for satellite distribution of three television channels to more than 150 public television stations around the country. By the mid-1980s, building satellites with the capacity to relay 100 television channels with multiple spot beams at 12 GHz or above should be technically feasible. However, it remains doubtful whether a demand for this many television channels will materialize.

Direct satellite broadcasting (DBS). The trend toward higher satellite power and smaller earth stations leads to the concept of direct television transmission from the satellite to a rooftop antenna. This is known as *direct satellite broadcasting.* DBS would bypass terrestrial television transmitters and cable television networks by providing national distribution of multiple television channels directly to the home. Consequently, DBS is highly controversial politically—in the United States because of concerns about preserving local television service, and in other countries because of concerns about television transmission across national borders without government control. The choice of whether or not to adopt direct satellite broadcasting will therefore be based more on political than on technical or economic factors.

There is no question that DBS is technically feasible. The principle issue is the cost of the rooftop satellite receivers in comparison with over-the-air broadcast antennas and cable distribution systems. The cost of a satellite receiver depends on the size of the antenna, which depends, in turn, on the transmission frequency and the power of the satellite. Transmission at 2.5 GHz (suggested for some educational channels) might require a 3 meter antenna, for example, while transmission at 12 Ghz could use a .75 to 1.5 meter antenna. Today, at volumes of 10,000 or so per

year, the installed cost of a 1.5 meter antenna would be around $1,000. Of course, manufacturing costs (but not installation costs) would fall with mass production. A recent study for the National Research Council reported that a 1.3 meter antenna capable of receiving 12 color television channels transmitted at 12 GHz could be installed for about $250 if mass produced in the millions.[24]

Even at $250, a satellite receiver would be far more expensive than an ordinary broadcast antenna and considerably more than the average cost per household to build a 12-channel cable television system. Moreover, it is not clear what advantages direct satellite broadcasting would have for U.S. households in metropolitan areas. Rural Alaska could certainly utilize satellite broadcasting; but in other U.S. rural areas, such a system would seem to be less cost-effective than extending over-the-air television service with translators. Proponents of direct satellite service to rural areas usually cite the ability to carry instructional television, video teleconferencing, and other subsidized noncommercial services once the basic system is in place.

Direct broadcast satellite systems seem more economically attractive in developing countries and in nations with widely dispersed, low-density populations. Canada, Brazil, Indonesia, Australia, India, and the Soviet Union, among others, are interested in the concept. Japan is pursuing the technology most aggressively, with a direct satellite broadcast experiment scheduled to begin in 1978, even though Japan seems well-suited for conventional broadcasting and cable television distribution. The Japanese may well foresee a large export market for direct broadcast satellite terminals in the 1980s.

Point-to-point satellite services. The use of satellites for point-to-point services should expand significantly when systems designed for small earth stations are introduced in the 1980s. Satellite Business Systems plans to use earth stations installed on office rooftops, each with sophisticated computers for signal processing and channel assignment. Such terminals would today cost more than $300,000, but SBS expects their cost to drop below $200,000 by the early 1980s. Other point-to-point satellite systems, such as that proposed by the Public Service Satellite Consortium, could be designed for lower cost earth stations with considerably less communications capacity.

SBS has tailored its system for large communications users who can justify the cost of dedicated earth stations. Voice, data, facsimile, video, and other traffic will be combined into a single digital bit stream at the sending terminal, transmitted to the satellite in short bursts under computer control, and switched at

the satellite for transmission to the proper receiving terminal. Customers will use only as much bandwidth as they need for the time they need it. End-to-end service costs will depend on the volume and type of communications transmitted, but the costs are expected to be below those now charged by other carriers (SBS has not yet filed tariffs). Based on the SBS cost projections filed with the FCC, a large user's average cost to send a page of text from one office word processor to another will probably be between 1 and 10 cents, independent of the distance between sending and receiving terminals.

The SBS system should be particularly attractive to customers located far from the large earth stations operated by other satellite systems. The system should encourage more data, message, and text transmission among geographically dispersed offices and industrial plants. Moreover, unlike AT&T's present competitors, the SBS system will directly link end users, bypassing the terrestrial telephone network with its local loops and switching hierarchy. AT&T would also be able to offer its own roof-to-roof satellite service if it chose and were permitted to do so. Thus, technically at least, the stage is set for end-to-end competition among AT&T, SBS, and other satellite carriers in the early 1980s.

One particularly interesting application of satellite communications is that now used by the *Wall Street Journal*. Each evening, the next day's newspaper is composed in New York City and transmitted digitally by satellite to three regional printing plants for simultaneous printing and distribution. During the next decade, other publications are likly to use this technology to achieve rapid printing and national distribution of their products.

By the late 1980s, even more powerful satellites launched by the space shuttle could be used to link vehicle-mounted or hand-held mobile transceivers. Regional or national mobile communications networking by satellite therefore appears to be a technical, although not necessarily cost-effective, possibility. However, such a development would require substantial spectrum reallocation in the UHF or another region. One other possible application of satellite technology in the 1980s would be to monitor large-scale, geographically dispersed sensor arrays that could detect forest fires, floods, and even oil spills. Although this again appears technically feasible, the economics of large sensor systems remain questionable. These and other applications could be tested by experimental satellite programs in the early 1980s.

Optical Fiber Transmission

Technical developments in lightwave communications. The technology for transmitting signals with light over glass fibers has matured so rapidly that lightwave communications has been brought from laboratory development to commercial introduction within five years. Optical fibers are smaller and lighter than coaxial cables or wire pairs. They offer increased transmission capacity and avoid electromagnetic interference with other signals. Optical fibers are already in use in military systems and are undergoing commercial tests in computer, telephone, and cable television systems. They appear likely to replace copper wires and coaxial cables for many new high-capacity data and video links in the 1980s.

All of the components required for lightwave communications are in a rapid state of technological advance. Losses and distortion within the glass fiber itself have been reduced sufficiently so that the fiber can carry more than 100 megabits per second—enough for 1,500 voice conversations or 2 television channels—more than 7 kilometers (4 miles) without amplification. The fiber's usable bandwidth remains limited by light dispersion, but it, too, is improving remarkably. Projections for the 1980s suggest that a single, hair-sized fiber will be able to carry half a billion bits per second. However, in many applications it may be more economical to use additional fibers in parallel, rather than to push a single fiber to its capacity limits. Given their small size, a number of lower-capacity fibers can be run together in a cable to fill virtually any transmission need.

Both light-emitting diodes (LEDs) and solid-state injection lasers are available as sources for lightwave communications. Today, LEDs are less expensive, more reliable, have longer lifetimes, and are better suited than lasers for analog signal modulation. However, LEDs have greater usable bandwidths. Thus, as their lifetime and reliability improve, injection lasers should become the dominant light sources in the next decade. Silicon photodiodes provide inexpensive and reliable detectors, and more sensitive detectors (avalanche photodiodes) are available for high-performance applications. Repeaters that can be directly integrated with the fiber transmission line have been built experimentally and should be commercially available by 1980. Low-loss splicing techniques, which had previously posed a barrier to practical fiber installations, have also been developed. The technical trends therefore suggest several commercial uses

of optical fiber transmission in telecommunications systems of the 1980s.

Optical fiber transmission in the telephone network. The first widespread applications of optical fibers in the telephone network will be for video transmission and for digital trunks connecting switching offices within metropolitan areas. The small size of optical fiber cables is particularly attractive in urban areas, where underground duct space is limited. The standard data rates for interoffice trunks (1.544 Mbps, known as a *T-1 rate*, and 44.7 Mbps, known as a *T-3 rate*) are technically feasible today for optical fiber transmission.

AT&T successfully field-tested optical fiber transmission at 44.7 Mpbs in Atlanta during 1976. Further tests are proceeding in Chicago (AT&T), in Long Beach, California (GTE), and outside of London (ITT), among other places. By 1980, industry sources expect the cost of optical fibers to fall from the present level of $1 per meter to around 10 cents per meter. This would make fiber optics cheaper than the special video cables now installed by the telephone carriers, and should lead to their rapid adoption for video transmission in metropolitan areas. As costs fall, optical fibers will also become competitive for the T-1 digital trunks now carried on wire pairs. Optical fibers could begin replacing these copper wires in the early 1980s and are likely to be the preferred choice for interoffice trunking by 1985.

Long distance transmission requires higher data rates. Field tests in England achieved rates up to 140 Mbps in 1977. Bell Laboratories is developing a 274-Mbps optical fiber system capable of carrying more than 4,000 voice channels. Such a system might well be competitive with other long distance transmission links by 1985, and so that we may see the installation of long distance optical fiber transmission lines in the late 1980s. However, for the following reasons, the Bell System may not have a great need for additional long distance terrestrial facilities at that time: (1) Bell's long distance traffic may not be growing as rapidly in the 1980s as in previous decades due to competition and some saturation of demand. (2) New satellite systems may be able to handle much of the increased traffic. (3) AT&T plans to expand the capacities of its present coaxial and microwave systems on existing rights of way. Consequently, although optical fiber systems may be cost-competitive with other new terrestrial facilities, the demand may not warrant their construction. Optical fibers appear likely to be feasible for some undersea cable installations by the mid-1980s.

Microwave, Cable, Wire-Carrier, and Waveguide Transmission

Significant improvements are also under way in the "conventional" microwave, coaxial cable, and wire-carrier transmission systems. New single sideband (SSB) equipment can double or treble the capacity of existing microwave links, and higher frequency microwave systems are available as well. Consequently, present microwave routes can be upgraded in capacity at relatively low cost, because new rights of way will not be needed. The capacities of coaxial cable transmission systems have also improved. New systems can carry more than 13,000 voice channels per coaxial pair, or as many as 132,000 channels along each route. The installation of new repeaters can double the capacity of the digital T-1 links carried on wire pairs in metropolitan areas. And higher capacity digital carriers (T-2, carrying 96 voice converstions, or 6.3 Mbps) have been introduced into the urban network.

As outlined above, these improvements may limit the extent to which optical fibers are needed for long distance transmission. Together with the developments in optical and satellite systems, these improvements also signal the demise of millimeter waveguide transmission, which was considered among the most exciting new transmission technologies a decade ago. Waveguide technology has advanced considerably in the past ten years, but it appears doubtful that it will compete in the 1980s with other transmission systems.

The Trend toward Digital Transmission

Although microwave transmission systems are likely to remain analog because of bandwidth limitations, most new guided-wave transmission systems in the 1980s—wire carrier, coaxial cable, and optical—will be digital. This reflects not only the expected growth in digital data communications, but also the following general advantages of digital transmission.

- Efficient integration of voice, data, video, and other services.
- No cumulative signal degradation with increasing distance.
- Better error control.
- Prospects for increasing transmission efficiency through signal processing and coding techniques (bandwidth compression).

- Likelihood of large cost reductions in LSI digital circuitry.
- Opportunities for greater privacy and security.

These advantages hold for digital transmission of voice and other analog signals as well as data.

Digital and packet networks. Still, the bulk of the existing telephone plant is analog. As a result, the telephone carriers and their competitors have developed separate, digital facilities to serve data users. AT&T, by adapting a section of existing analog microwave links for data (called *data under voice*, or *DUV*) and by other techniques, now provides end-to-end digital service to more than 50 cities. Bell plans to expand the Dataphone Digital Service (DDS) network as quickly as the FCC and state regulators allow. Competitors also hope to expand their present facilities and to introduce new satellite and terrestrial digital transmission links in the next decade. Throughout the 1980s, however, digital transmission networks will be separate from AT&T's switched-voice network, which will remain a hybrid of analog and digital facilities.

Packet networks, described previously, will be widely used in the 1980s for transmitting digital data and messages among terminals and computers. Once in place, these networks can be used to transmit voice messages as well. Packet services are now available commercially in about 80 cities. Like end-to-end satellite communications, packet services are designed for business data users who can afford the required processors at each terminal. At present commercial prices, a large user's average cost to send a page of characters or 20,000 bits runs between 5 and 25 cents; the marginal cost per page is about 1 cent. Prices should decline in the future and will probably be competitive with satellite transmission, although this will be determined more by market than by technological factors.

The telephone carriers presently lease digital circuits to other firms that provide packet services, but there is every indication that AT&T and other carriers plan to offer packet services of their own. Bell's Transaction Network Service (TNS) for credit checking and point-of-sale communications represents a clear step in this direction. If AT&T is successful in establishing TNS on an intrastate basis, it will surely try to generate other data services over these facilities, as well as extend them to form a national packet network. Many observers expect that AT&T will announce plans for such a Bell Data Network in the next year or two. Electronic funds-transfer systems also will use the packet-switching concept over digital facilities.

Toll-call signaling (CCIS). Another innovation, known as Common Channel Interoffice Signaling (CCIS), illustrates the growing use of digital transmission in the switched-telephone network. CCIS transmits the information necessary to route a call through the toll network over digital circuits separate from those used for the call itself. At present, call-control information is transmitted as analog tones in the voice-frequency range, giving the familiar series of "beeps" heard when one places a long distance call. With CCIS, call-control information can be transmitted at high data rates, enabling toll calls to be set up much faster on the switched network. This is vitally important for data transmission that sends short bursts of pulses between computer terminals.

Besides using toll circuits more efficiently, CCIS brings several additional advantages to the telephone carriers. It encourages use of the switched network for both voice and data. A separate circuit for call-signaling deters unauthorized use of the toll network by those who have assembled their own call-signaling devices. CCIS also carries the number of the calling party throughout the network as it sets up a call, thus making it possible to offer a number of new services. An intelligent telephone, for example, could display the caller's number while the phone was ringing, or provide a different tone for preselected "important" callers.

CCIS would also allow a nationwide firm to establish a single, toll-free "800" number and have calls routed automatically to the nearest local office. Another commercial service would be to provide a business customer with a list or computer tape with the names, addresses, and phone numbers of everyone who had called. Commercial subscribers could then use this information for, among other things, preparing advertising mailing lists. Such a service raises questions of privacy, however, especially if unauthorized parties could obtain such lists.

Finally, CCIS provides the technical means to offer other data services over its high-speed digital links, similar to those provided by the packet networks described above. The Bell System has made a major commitment to CCIS and expects to have it operating among large switching centers by the early 1980s.

Privacy on digital networks. Despite issues of privacy that may arise from new developments such as CCIS, digital communications in general offer technical prospects for increased privacy and security. Combining pulses from voice, data, and other services into a single digital bitstream makes it more difficult for amateur eavesdroppers to discern individual conversations or messages. Of course, a professional wiretapper with a computer

could sort out information on a digital channel, but this would require training and dedication, as well as some sophisticated equipment.

Digital signals can also be coded or encrypted more easily than analog signals. IBM has developed a mathematical data encryption procedure that provides considerable security protection and is relatively easy to implement on a communications channel. This algorithm has been accepted by the National Bureau of Standards and seems likely to be generally adopted for commercial encryption. An LSI chip to implement the IBM algorithm is relatively inexpensive—$50 or so in large quantities—but the additional electronic circuitry needed to build encryption into a communications terminal may cost several hundred dollars or more.

Many business and government users seem willing to pay this price to increase communications privacy and security, but it is clearly too high for use in a home telephone. Also, although encryption and other techniques can be used by the telephone carriers on digital long distance channels, these techniques would not protect subscribers' local loops, where eavesdropping can most easily occur. When digital channels finally reach the home, a less expensive encryption circuit could be offered as a plug-in module to an intelligent telephone. Of course, it would be useful only for communicating with others who had similar decoders and appropriate keys. There is no indication that residential telephone (or cable television) subscribers would be willing to pay substantially more for greater assurance of privacy, but digital encryption is technically feasible and could be offered as an added service by communications carriers.

Switching Technologies

Computer-controlled switching. The major switching innovation in the past decade has been the introduction of computer-controlled switching in local central offices, often called *electronic switching.* The Bell System's No. 1 ESS is an example of a computer-controlled switch; other telephone companies and independent manufacturers produce comparable equipment. Computer-controlled switching has not meant a change in the basic switching mechanism itself, which relies on physically making and breaking electrical contact between circuits—a technique still oriented toward analog voice communications. Rather, computer control makes such electromechanical switching faster and cheaper in large telephone exchanges, and far more adaptable to changing calling patterns.

To the telephone subscriber, computer-controlled switching brings the introduction of pushbutton telephones, faster call connections, and the availability of new services, such as those listed in *Table 2-3*. To the telephone carriers, computer-controlled switching means lower switching costs per line, more flexibility of service, and opportunities to earn new revenues. Besides offering new calling features, computer-controlled switches permit inexpensive automatic recording and billing of both toll and local calls. This makes usage-sensitive pricing of local calls considerably more attractive to the telephone carriers.

If the trend toward usage-sensitive pricing continues, the telephone carriers will have more incentive to introduce (or encourage others to introduce) information-oriented services, such as those being developed by the British Post Office for its Viewdata system. Thus, automatic local-call billing, made possible by computer-controlled switching, seems a key to introducing a wide array of information services accessible over the telephone network. The conversion of some 20,000 telephone central offices from one switching technology to another is a formidable task involving an investment of tens of billions of dollars. AT&T has programmed the introduction of computer-controlled switching over 40 years. As of early 1978, 13 years after the first No. 1 ESS switch was introduced in the Bell System, only about 25 percent of subscriber lines were connected to computer-controlled switches. It will be the mid-1980s before half of the Bell System's lines are served by computer-controlled switches, and well into the 21st century before the conversion is completed.

The introduction of computer-controlled switching in the independent (non-Bell) telephone companies that serve predominantly small towns and rural areas has been even slower. Computer-controlled switching exhibits economies of scale, so that costs per subscriber are higher in small exchanges. This has led to the concept of a single computer-controlled switch handling several small exchanges via remote links. The Rural Electrification Administration and several independent companies are actively pursuing this approach. Still, the majority of non-Bell subscribers will probably not be served by computer-controlled switches during the 1980s.

Digital switching. Even as telephone central offices have begun converting to computer-controlled, electromagnetic switches, a different approach to switching has been developed that more fully integrates computer technology and is more compatible with digital communications. In digital or "time division" switching, the conducting paths connecting external circuits are not physically opened and closed. Instead, the data pulses associated

with a given incoming signal are identified and sorted onto the correct outgoing circuit. In essence, a digital switch acts as a timed electronic gate, opening and closing under computer control.

Some of the newer computer-controlled PABXs employ digital switching, and digital switches (No. 4 ESS) are beginning to be installed in the toll telephone network. By 1990, the Bell System plans to route more than 75 percent of toll calls through digital switches. In 1977 the first commercial digital switches were introduced into a few independent telephone local exchange offices. However, no plans have been announced to bring digital switches to AT&T local central offices, even though many experts outside the Bell System believe them to be technically superior to the computer-controlled electromechanical switches scheduled for installation over the next 25 years.

Local Distribution

Broadcast radio and television, telephone wire pairs, and CATV coaxial cables are today's principal modes of local distribution. Each of these modes will evolve technically during the 1980s; but the distinction between voice and other narrowband services delivered over the switched telephone network, and broadband services provided on a cable distribution network, is likely to continue. Substantial expansion of mobile two-way communications should also occur throughout the decade, but portable telephones are likely to remain too expensive for most households. Optical fiber distribution will be introduced principally for commercial and government applications. Although integration of the cable and telephone networks may become technically feasible, it seems unlikely to be implemented before 1990.

Telephone Wire Pairs

The copper wire pairs running from telephone central offices to subscribers have been well-engineered to carry voice conversations and other analog signals—otherwise known as POTS, for Plain Old Telephone Service. No changes in metropolitan area local loops are needed to handle POTS. However, where underground ducts are already filled, or in rural areas with long local loops, more electronics may be placed between the subscriber and the central office to cut down on the number of necessary wire pairs and to improve service (e.g., to provide single-line rather than party-line service).

Local loops designed for POTS will also carry digital data at speeds that can fill a CRT display with text in a few seconds—

fast enough for information and message services to the home. Higher speed services up to 56Kbps can be distributed on special wire pairs that are engineered for digital data. In a business or institutional environment that makes heavy use of voice, data, and other communications, the technical trend is to concentrate the traffic at the subscriber's premises and transmit it digitally to the telephone central office. This is a principal function of the computer-based PABXs that will be commonly used by commercial subscribers in the 1980s. Some computer-based PABXs will connect directly to a digital switch in the toll network to avoid analog switching at the local central office.

Coaxial Cable Television

Cable television has evolved over the past 30 years to a reasonably mature technology for distributing television signals one-way from a central source (the headend) "downstream" to multiple subscribers. State-of-the-art cable systems can carry 30 to 35 television channels on coaxial cables attached to utility poles or installed in underground ducts. About 12 million households currently are cable subscribers; forecasts for 1985 range from 20 to 40 million.

Technical advances in coaxial cable technology in the next decade will be modest and evolutionary. Systems will be designed for greater reliability, lower distortion (and, hence, improved signal quality), and lower cost. Increasing the number of channels carried per cable is technically feasible, but not likely to be a major design emphasis, since few cable systems use the 30 or more channels they now can carry. Consumer demand for high resolution television, in conjunction with projection television or large flat-panel displays, would call for additional downstream bandwidth and perhaps digital television transmission to the home. However, neither seems likely to be a major factor in cable system design during the next ten years.

New cable systems in metropolitan areas will typically have several distribution points, or hubs, each with its own cable distribution network to subscribers. The hubs will be interconnected by microwave, coaxial cable, or (within five years) optical fibers and will be linked to other cities by satellite or terrestrial transmission. As a consequence, more cable systems will be able to provide channels from other cities, as well as nationally syndicated pay-television and other programs unavailable on broadcast television.

Portions of the cable bandwidth can be reserved for local video channels, computer data, or any other form of communications

service. If the system is carefully engineered, some digital data can be carried along with the analog television signals on the same cable. Few cable systems today are designed to carry data, but the urban systems of the 1980s probably will be.

The technical capability for two-way cable communications—that is, for sending signals "upstream" from the subscriber to a hub or headend—was developed in the last decade but has been relatively little used. Two-way cable systems can reserve a certain bandwidth (usually 6 to 30 MHz) for upstream communications, using electronic filters to keep these signals from interfering with the downstream flow. Carrying signals in both directions on a single cable is not without problems, including added distortion, added cost, and sensitivity of the upstream signals to noise introduced at each television receiver. But it is technically feasible to send data, voice, and video signals upstream from the subscriber to a hub or headend.

Other technical possibilities for two-way cable communications include looping the cable back to the headend, or installing a separate wire or cable for the upstream link. Most new urban cable systems are designed for eventual two-way operation with an added investment of 15 to 30 percent. However, a more practical approach for many proposed interactive services is to use the telephone lines for the return link from the subscriber to the headend.

Cable systems have not yet found the combination of new services that would justify the added cost of two-way transmission or switching capabilities. In some metropolitan areas, cable companies may be able to compete effectively with the telephone carriers for the distribution of data and closed-circuit video services to institutional subscribers. But to date, the principal new service to the home is pay-television. More than one million households now subscribe to pay-television on cable. Their numbers are forecasted to double by the early 1980s. Broadcast pay-television is now available in Los Angeles and is scheduled to begin operation in several other U.S. cities by 1980.

Most cable systems now provide pay channels at frequencies not used for their basic services and install a special converter for each pay-television subscriber. This arrangement makes it relatively easy for subscribers to obtain their own converters and get the pay programming for free. Consequently, cable systems are moving rapidly to install electronic "traps" that can filter out the pay channels for those who do not pay to receive them. Alternatively, an "addressable tap" can be installed that allows pay programming to pass through upon a signal from the headend. Systems also can scramble or code the pay-television signals and

provide a home decoder. Decoders are more expensive than frequency converters, but the decreasing cost of logic is bringing their cost down to below $100. Broadcast pay-television systems must use decoders, since all viewers in the area receive the same broadcast signals.

Pay-television subscribers today pay a fixed monthly charge for the special channels. This avoids the need for identifying and recording when subscribers are watching a particular pay program. However, per-program charging seems desirable from both the industry's and subscribers' standpoint. Several technical approaches to per-program charging are feasible and have been tried with moderate success. One approach is to record (on a card or magnetic strip) at the subscriber's terminal all pay programs watched, and then to have the subscriber periodically mail the record for billing purposes. An alternative is to have the subscriber dial a special access code by telephone, which then produces a signal from the headend to the subscriber's addressable tap or home terminal that permits viewing of the pay program.

Neither of these approaches requires two-way transmission on the cable system. However, two-way cable communication makes pay-television transactions much simpler. The subscriber can simply push a button to view a pay program, sending a message to the headend for billing purposes. Alternatively, a computer at the headend can routinely poll each subscriber's terminal to determine whether or not a pay program is being watched, and then record the result automatically.

Each of these technical approaches has advantages and disadvantages. The reduced costs of LSI logic and memory should favor installation of more sophisticated terminals in the home for pay-television billing. However, the fact that pay-television can be implemented relatively inexpensively on a one-way basis inhibits the introduction of two-way cable services.

Mobile Communications

Among local distribution modes, mobile communications stand to gain most from advances in LSI technology. Mobile systems of the 1980s will make extensive use of microprocessors and associated LSI circuits for signal processing and control functions in order to use the limited available frequency spectrum more efficiently.

Mobile communications include several different kinds of services:

- *Paging service*, requiring only one-way transmission from a base station to a portable paging unit. Most paging units today sound a tone or otherwise signal the user to call the paging service for a message. Advances in LSI circuitry will allow pocket pagers to record or display a brief message (e.g., the name and telephone number that the paged party is to call), as well as reduce the cost of paging receivers substantially below their present level of about $250.
- *Citizens band (CB) radio*, "party line" broadcasting channels over which any user can send and receive messages. CB radio has proved immensely popular in the past few years, but equipment sales have slowed recently, and there are signs of consumer saturation. Although CB radio channels have been used for data transmission (e.g., between computer hobbyists), the high congestion makes CB radio technically less desirable for such uses than two-way dispatch or mobile telephone services.
- *Dispatch and mobile telephone services*, requiring two-way communications between a fixed base station and a mobile unit, or between two mobile units. Dispatch services for taxis, ambulances, delivery vans, and other vehicles have traditionally been distinguished from mobile telephone service because they transmit very short messages, and consequently more users can share a given bandwidth. Technically, the two services are quite similar and can be provided on the same physical system. Mobile telephone base stations connect with the "wireline" carrier network to transmit calls between mobile users and fixed telephones.

In addition, telecommunications technologies are applicable for such other mobile functions as vehicle location, identification, and control.

The growth of mobile telephone services has been severely limited by the restricted frequencies made available by the FCC. Older mobile telephone units had fixed assigned frequencies which generally could not be shared by other users. Newer units share a block of channels, known as Multi-Channel Trunked Systems (MCTS), and automatically search for a free channel on which to transmit. Still, an MCTS transmitter broadcasts throughout its mobile service area (MSA), thus denying that frequency to other users and consequently limiting the total number of mobile units within the MSA. Current FCC guidelines recommend only 40 mobile telephone subscribers per channel on a 5-channel MCTS system.

Cellular mobile systems. One technical approach to expanding the number of mobile users is to reassign or "reuse" frequencies within a mobile service area. This is done by dividing a large MSA (typically covering several thousand square miles) into smaller cells ranging from one to eight miles in radius. Each cell contains a low-powered base station transmitter, with transmitters in adjacent cells operating at different frequencies. Frequencies used in one cell can then be reused in other non-adjacent cells within the MSA.

A cellular system can accommodate roughly 3 to 50 times the number of mobile units as the conventional multi-channel trunked system, depending on cell size and the frequency-assignment scheme. The smaller the cell size, however, the more elaborate the processing capability required at the base stations and mobile units to allocate of channels and "hand-off" units from one frequency to another. Fortunately, computer-controlled telephone switches and LSI-equipped mobile units can adequately handle such complexity at a cost roughly comparable to that of MCTS systems—about $1,500 to $2,500 per subscriber.

In 1974, the FCC authorized an additional 115 MHz for mobile communications, of which 40 MHz was allocated to the telephone carriers for development of cellular mobile systems. AT&T plans to test its first cellular system in Chicago in 1978 and to begin regular commercial service by 1980. The Bell system estimates that it can have cellular systems operating in 25 urban areas by 1985.

Digital packet radio. An alternative new technology for mobile communications is digital packet radio. In a packet radio system, a mobile unit transmits bursts of digital pulses using the entire mobile frequency band, rather than transmitting continuously over an assigned frequency channel. The pulses are passed along by fixed repeaters to a base station, where the information is either transmitted to the receiving mobile unit in the same MSA or sent out over the wireline network. The advantages of a packet mobile radio system, like the advantages of digital communications in general, are the system's ability to integrate voice and data communications efficiently, its flexibility in handling varying demand patterns, and its extensive use of LSI digital circuitry, which promises large cost reductions over the next decade.

Packet radio would be particularly suited for mobile data transmission. For example, the address of an ambulance or taxi pickup could be displayed in the vehicle, instead of communicating with the driver by voice. Similarly, a newspaper reporter could transmit story copy directly from the scene of the news event. With packet radio, a portable computer terminal would serve as an

office. The principle disadvantage of the packet radio system is that, without bandwidth compression, digital transmission of voice conversations represents an inefficient use of the limited spectrum available for mobile communications. As bandwidth compression and coding techniques become less expensive in the 1980s, packet radio will become more competitive for analog voice transmission.

Developing either cellular or packet mobile systems would allow mobile telephone service to grow from its present level of about 200,000 users to perhaps several million subscribers by 1990. Although costs should come down somewhat from present tariff levels, mobile users probably will still pay several times the cost of regular telephone services. As a result, two-way mobile telephony in the 1980s will remain a service principally for business and professional users. Consumer demand may open up additional CB radio channels, but broad expansion of other mobile services to the general public would require even more spectrum reallocation and therefore appears more than a decade away.

Optical Fibers

The spectacular advances in optical communications technology over the past few years make optical fibers attractive for local distribution, as well as for long distance transmission of video, voice, and data services. This development will occur first among business and other institutional users. Optical fibers are already in use for high-speed computer-to-computer links in data-processing centers. They should soon also be practical as well for distributing video and high-speed data within an office building or commercial center.

In factories, optical fiber links are particularly good for protection against electrical interference, for eliminating damage to terminals due to damage to the link, and for personal safety. Providing the internal communications links to a rooftop satellite terminal appears to be another application. By the early 1980s, optical fibers may also provide the digital local loops from a computer-based PABX to the telephone toll network, or to a competitive transmission system.

The introduction of optical-fiber local loops to home telephone subscribers appears to be further away. Wire pairs are adequate for voice and low data-rate communications. Consequently, even though optical fibers might be less expensive than copper wires for new installations within the next decade, the lower cost would not justify the expense of removing existing local loops

(unless the cost of copper increased to a point where it became profitable to recycle telephone wires). Moreover, wire pairs carry direct electrical current to the home, providing power for the telephone, ringing voltages, and several other control functions. Since optical fibers are nonconducting, these functions would still have to be provided with conducting wires, or by using the subscriber's electric power, which would make telephone service more vulnerable to power failures. The conclusion is that optical fibers are unlikely to replace telephone wire pairs for residential local loops until a demand arises for switched broadband services to the home. Picturephone represents one such possibility, but there is no indication that this service will have arrived by 1990.

Optical fibers will be used for cable television distribution in the 1980s, although not as quickly or pervasively as some enthusiasts have forecast. Costs are still high (though dropping rapidly), and intermodulation distortion limits the capacity of present fibers to two or three analog television channels. However, within three to five years, optical fibers could be competitive with coaxial cable and microwave links for interconnecting cable system headends, distribution hubs, studios, and satellite receivers. TelePrompTer successfully demonstrated such an application in New York City in 1976. Within the next decade, optical fibers seem likely to supplant coaxial cables as trunks and feeders in some new systems, particularly those installed underground. The choice to use optical fibers rather than cables will be made on the basis of installed cost, rather than on the fiber's potential for increased capacity. And these initial installations are likely to be on conventional, entertainment-oriented, basically one-way television distribution networks.[25]

A conservative scenario thus shows optical fibers in the 1980s gradually spreading from cable system headends and hubs to trunk lines and then toward the final link to the home. By 1990, a small but growing fraction of the nation's television distribution plant will be optical. Eventually, it will prove economically feasible to bring a switched, two-way optical system to residential subscribers. At that point, a single integrated network for the distribution of television as well as telephone services may be preferable to maintaining separate systems. On the other hand, the advantages of having competitive links to the home may overshadow any cost savings from integration.

The decision whether the communications system of the 21st century will have a single superhighway or two parallel expressways to the home will undoubtedly be made on political as well as economic grounds. The technology will be available to support either approach.

Notes

1. Had the mechanical calculator industry been regulated, we might still be waiting for delivery of electronic gate-to-electromechanical gear converters, rather than buying $9.95 electronic calculators at the supermarket.

2. The number of components per chip is several times greater for LSI memories, with their regular, repetitive arrays, than for microprocessors. The technological improvements expected during the next five years include the manufacture of larger chips, higher production yields, and the use of electron beams and x-rays to form even smaller components. LSI technology has advanced so rapidly that component density now is limited by the wavelength of light used to expose photolithographic patterns on the chip, and by the additional interconnections needed as the number of components increases. The size of the "wires" between components rather than the components themselves has become the limiting factor. See Ivan E. Sutherland, Carver A. Mead, and Thomas E. Everhart, *Basic Limitations in Microcircuit Fabrication Technology*, The Rand Corporation, R-1956-ARPA, November 1976.

3. The common unit of information is the binary digit, or bit. A single bit can be represented by the on-off switching of an electrical current in a simple telegraph system. As in telegraphy, letters, numerals, and other characters can be formed by a succession of on-off signals, or bits. Conventional telegraph systems have used five bits for each character, with a "shift" character to indicate whether a letter, numeral, or other character is being transmitted. This data code is still used for Telex transmission. Other forms of data transmission and storage typically use a seven- or eight-bit code to designate alphabetical and numerical (alphanumeric) characters, without need for a shift character. The "ASCII code" is the U.S. standard version of a seven-bit-per-character data code. In a teleprocessing system, an extra bit is often required for error correction purposes. Thus, eight bits become a standard unit—a "byte"—for computation and data storage.

4. An additional distinction is drawn between memory units whose data remain unchanged (e.g., the basic instruction set for a microprocessor, or a reference file of statistical data), and those whose data is changed or updated regularly (e.g., the stored results of a computation or a file of current stockmarket prices). The former are known as read-only memories (ROMs); the latter, as read-and-write or random-access memories (RAMs). ROMs are generally less expensive but less versatile than RAMs.

5. Using a data code with eight bits per character, a page of typewritten text with 24 lines, 80 characters per line represents 15,360 bits (15.4 kilobits). Facsimile scanning of that same page requires nearly 1 million bits (1 megabit). Storing each of the 310,000 picture elements in a standard U.S. television frame would require more than 2 megabits. A 200-page printed book contains about 4 megabits; the *Encyclopedia Britannica*, roughly 100 megabits.

6. The 525-line U.S. television standard limits the image quality of any large-screen television display. Consequently, unless new standards are introduced, consumers may not find large-screen television displays particularly attractive for home viewing.

7. Digital signals must be converted (modulated) to analog form before transmission over an analog channel, and demodulated before entering another digital system. The conversion devices are known as modulator-demodulators, or modems. Conversely, coder-decoders (codecs) are used to process analog signals for transmission over digital communications facilities.

8. In some word processing systems, individual units will share logic and memory functions, similar to minicomputer time-sharing systems.

9. Both professionals and their secretaries are assumed to have a terminal in the office of the future. Today's experience suggests that most professionals without prior exposure to computing systems (including those over 40) resist using a graphic terminal directly and hence will require printed materials. This seems primarily a generational problem; within ten years, most newly hired professionals and support personnel will have had some prior exposure to word processing. Word processing systems also will change the relative work roles of professionals, secretaries, and typists—a topic beyond the scope of this paper.

10. Another approach in current use is to use microfiche or other microforms to reduce physical storage requirements. This has advantages in storing handwriting, images and other graphics, and is currently less expensive than digital storage for most applications. Major disadvantages include problems of updating microforms and in transmitting them over communications lines. With memory costs declining at 30 to 40 percent per year, and with an increased emphasis on electronic document transmission, one expects to see digital storage chosen over microform storage for more systems in the 1980s. One also expects to see more integration of information processing and microform systems, as, for example, by maintaining an index of microform records on the computer system.

11. Henry D. Taylor, Jr., "HP-Communication System," *Proceedings of the National Telecommunications Conference*, Los Angeles, December 1977, pp. 21:6-1 to 21:6-5.

12. Raymond R. Panko, "The Outlook for Computer Mail," *Telecommunications Policy*, Vol. 1, No. 3, June 1977, pp. 242-253.

13. Cost comparisons are difficult to make and interpret, since electronic message transmission will substitute for intra-company document distribution and telephone calls as well as the mails. Relative labor costs (currently estimated to be $6 to $8 per letter) are more critical than transmission or postage costs, as is the importance placed on speed of delivery. Given these uncertainties, estimates of first-class mail lost to electronic transmission by 1985 range from 20 to 60 percent.

14. Roger Pye and Ederyn Williams, "Teleconferencing: Is Video Valuable or Is Audio Adequate?" *Telecommunications Policy*, Vol. 1, No. 3, June 1977, pp. 230-241.

15. Frequencies and bandwidths are expressed in cycles per second, or hertz (Hz), and in multiples of thousands of hertz (kilohertz or KHz), millions of hertz (megahertz or MHz), and billions of hertz (gigahertz or GHz). Analog voice channels require a nominal 4 KHz bandwidth; U.S. television signals occupy 4.6 MHz within a nominal 6 MHz channel bandwidth. Digital data transmission is commonly expressed in bits per second (bps), kilobits per second (Kbps), and megabits per second (Mbps).

16. EFT systems already exist for funds transfer and settlements among banks. They include the FEDWIRE system which links the Federal Reserve Banks and their member commercial banks in each district; the BANKWIRE teletype network, which interconnects several hundred U.S. banks; the CHIPS network, which provides more comprehensive funds transfer services among New York City banks; and the SWIFT system for international funds transfer among 400 member banks in Europe and North America. See, for example, R. A. Hall, "Money Movement Transfer Systems," *Proceedings of the National Telecommunications Conference*, Los Angeles, December 1977, pp. 02:1-1 to 02:1-4. These interbank networks should grow rapidly in the next several years and provide a base of experience for further expansion into consumer EFT systems in the 1980s.

17. J. R. Pierce, "The Outlook for Communications," undated.

18. These features can also be provided by computer-controlled switches in telephone company central offices. In some cases, the sharing of equipment located at the central office may result in lower service costs. However, telephone companies may have incentives to install logic at the central office, which

they control, rather than place it at the terminal, which is subject to competition. Consequently, telephone companies may not be enthusiastic about implementing these services with intelligent telephones.

19. Another early application of LSI logic to U.S. television sets is for automatic picture tuning.

20. A single-line strip printer, as is contained in some hand calculators, can be added to any terminal device for about $50. It appears to have limited utility, although some users prefer it over a liquid crystal or LED display for records of transactions and short messages. A receive-only matrix printer for full-page printing would cost about $200.

21. To give some indication of its size and complexity, the Bell Telephone System now includes approximately 120 million telephones, 80 million local loops, 150,000 PABXs and key systems serving 30 million telephones and other terminals, 10,000 local central offices, and 1,000 toll switching offices connected by 1 million toll transmission trunks.

22. Interference may also arise between beams directed to or from different satellites. Current regulations require satellite spacing at approximately 3 degree intervals in their orbits around the earth. Thus, only about 25 satellites can be assigned to use the same frequencies over the United States, which covers a 75-degree arc. However, the capacity available is still quite large. A 500 MHz satellite bandwidth at 12 GHz could accommodate 220,000 telephone channels and 100 television channels with multiple spot beams. Improved technology could also permit closer satellite spacing in the 1980s.

23. International communications are not considered further in this chapter. For an account of possible future developments, see Ithiel de Sola Pool and Arthur B. Corte, "Implications of Low-Cost International Non-Voice Communications," unpublished report, Cambridge, Massachusetts, Center for Policy Alternatives, M.I.T., September 1975.

24. S. Metzger, "Possible Use of Satellite Transmission for Direct Broadcast TV in a Future Metropolitan Communications System," in *Telecommunications for Metropolitan Areas: Near Term Needs and Opportunities*. Committee on Telecommunications, National Research Council, Washington, D.C., 1977.

25. The availability of optical fibers will bring renewed interest in the concept of a switched television distribution service. In a switched system, television signals are distributed from a central source to a local distribution center serving some tens to hundreds of subscribers. Each subscriber has a signaling link to the distribution center and can select a television channel

with a special dial or pushbutton terminal. The subscriber's signal then switches the appropriate channel at the distribution center for transmission to the home. This concept was developed in the 1960s by Rediffusion, Ltd., using twisted wire pairs, and by Ameco, Inc., using coaxial cables for the link from the distribution center to the home. It was never successful in the United States because of high cost and the large number of wires required. Any switched system designed for the 1980s could include the capacity for services other than television, and two-way communications among local distribution centers. It remains doubtful, however, that this kind of switched system would be cost competitive with conventional tree or hub systems for television distribution, even with low-cost optical fibers. Some early tests of the concept may well occur, especially if the experiments using optical fibers for two-way communications that are scheduled in Japan during 1978-1980 prove successful.

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